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Isn't your car worth the extra pro

This One

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CLIMBER ZOOMS UP MOUNTAIN JUST BY USING HIS IQ.

You won't need backpacks or hiking boots to accomplish this feat, as long as you're smart enough to take along your IQ—the super slim IQ Zoom 700.

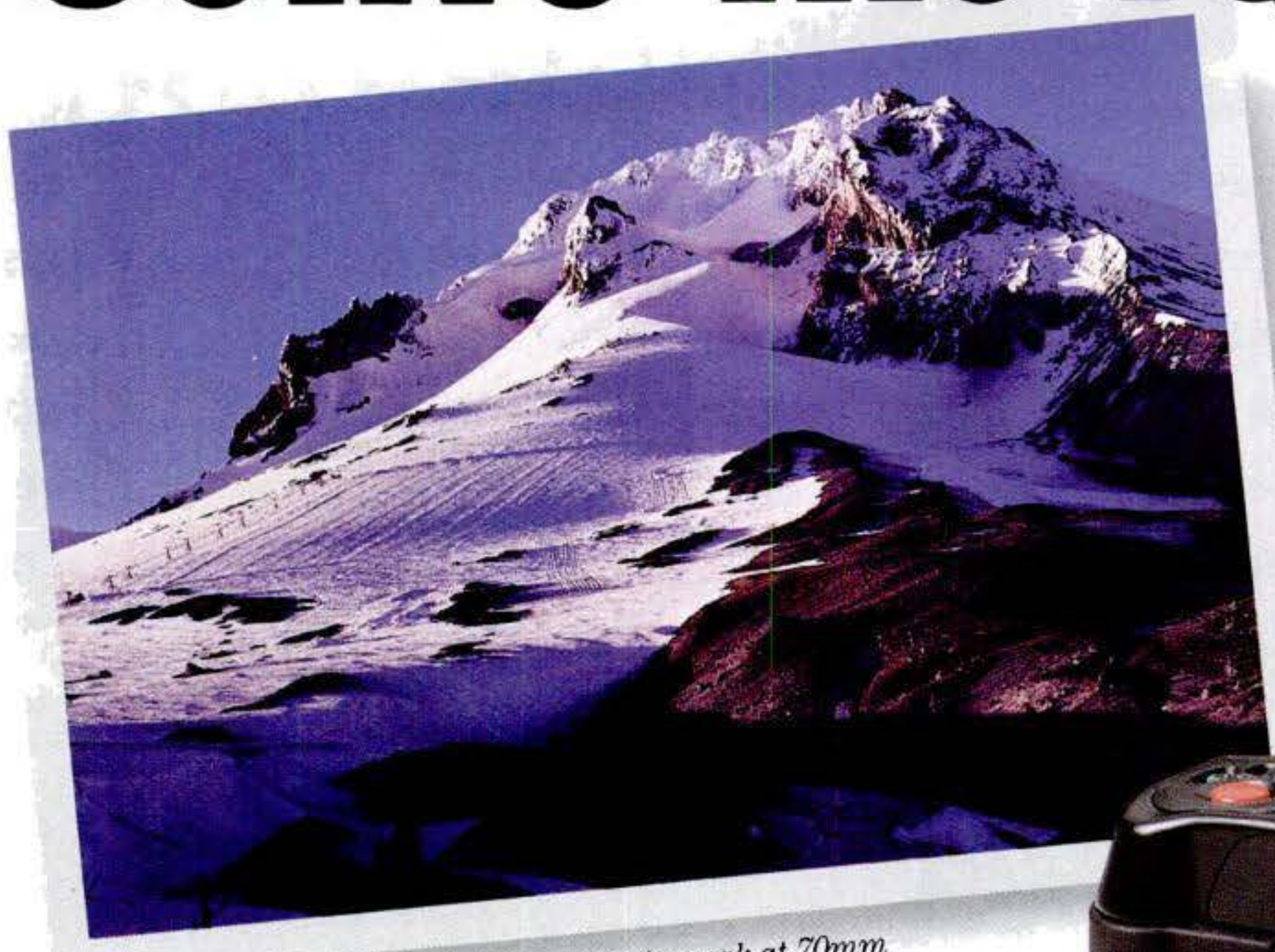
This incredibly compact camera offers a full range of automatic features that are simple to operate. So you can concentrate on enjoying the scenery instead of worrying about how to capture it.

The power zoom lens, first introduced by Pentax, lets you choose any focal length between 35mm and 70mm, plus a macro setting for close, detailed images.

The IQ Zoom 700 has many other features that lift picture-taking to new heights. Built-in auto flash, backlight compensation, daylight sync and slow-shutter speed sync assure beautifully exposed photos from dawn to dark, outdoors or in.

The pushbutton ease of this camera even has such unconventional features as a multi-exposure mode, and the self-timer lets you capture yourself as King of the Hill, twice, with only one setting.

See how easy it is to reach the peak of picture-taking? Just be smart enough to use your IQ.



Zooming reaches its peak at 70mm

PENTAX

IQZoom700

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King of the Hill at 35mm

Roped in by macro mode.

All pictures taken with the IQ Zoom 700 and Kodak Ektar film.

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Popular science

THE WHAT'S NEW MAGAZINE

OCTOBER 1990

Founded in 1872/Vol. 237, No. 4

COVER STORY 66

Earth-orbiting balloon

Earthwinds is the most complex manned balloon ever. Its mission: to fly around the world nonstop—a feat that has never before been accomplished.

How we can win the war on garbage

With landfills closing all over, what can we do with our ever-greater mounds of garbage? Some answers: degrade, recycle, burn.

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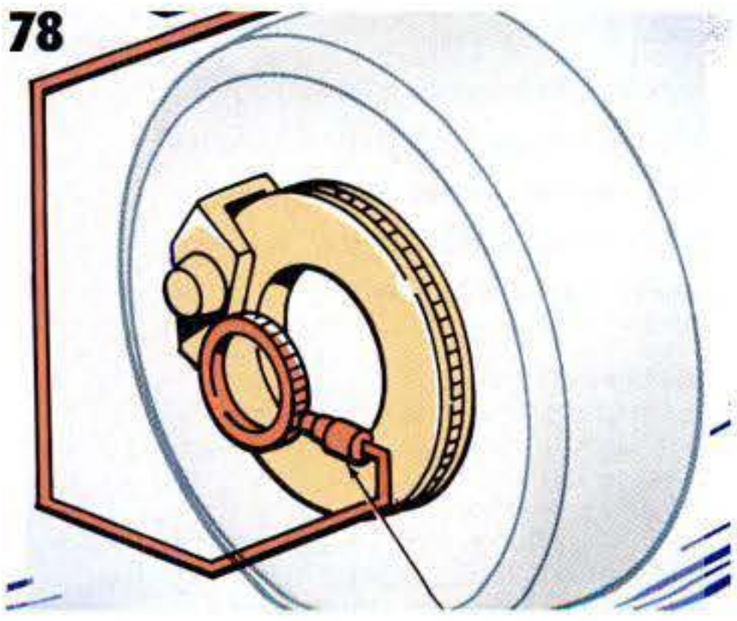
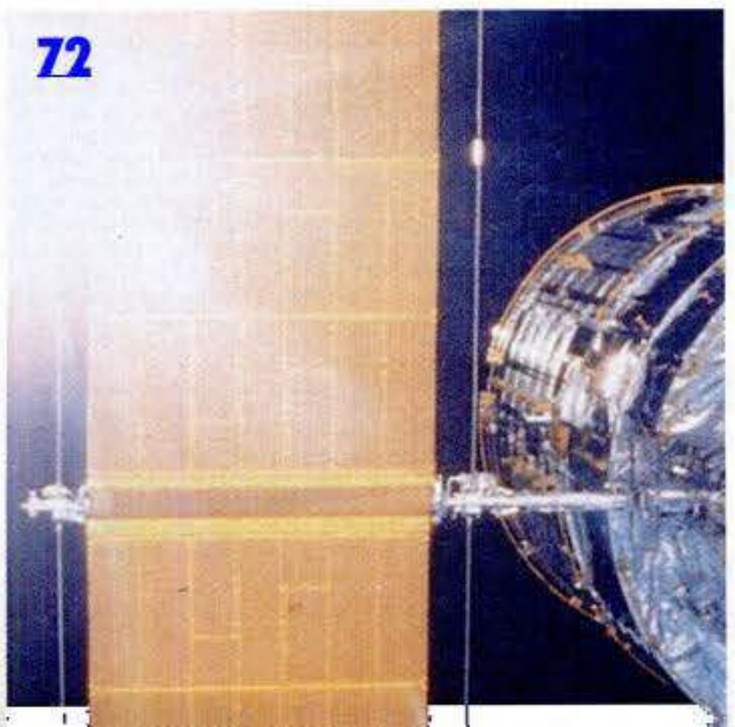


Antilock brakes

Antilock braking systems—costing upward of $1,200—have been a safety advantage that only a limited number of people could afford. But a new design strategy for ABS developed by Delco Moraine will drop the price to the $400 level, making it an option on mainstream domestic cars in 1991.

72



The trouble with Hubble

The Hubble Space Telescope should have been the greatest leap forward in astronomy since Galileo. But for now, the myopic telescope is a disappointment, an embarrassment, "a tragedy." Can the vision of Hubble be restored?

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COVER PAINTING BY JAMES IBUSUKI

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What's News

JOHN B. CARNETT

Pride of Maryland teammates surround POPULAR SCIENCE Editor-in-Chief.

On a dripping-hot, sunbaked July afternoon, the top-finishing solar-powered race cars of the General Motors Sunrayce USA gathered to be feted by the Department of Energy and POPULAR SCIENCE in Washington, D.C. Quite a contrast to the rain and wind the racers had slogged their way through only days earlier.

POPULAR SCIENCE's Engineering Excellence Award, a $2,000 scholarship, went to the University of Maryland team, whose Pride of Maryland racer finished third in the 11-day competition. Associate Editor Brian Nadel judged the Pride of Maryland "a safe car that is both fast and light."

With an average speed of 20.5 mph and first-place finishes in four of the eight daily legs that it completed under solar power, the Pride of Maryland's third-place overall earned it a sponsored ride to the trans-Australia World Solar Challenge race in November. And no one is holding a grudge that as pole-position starter, the Maryland team took a wrong turn that got everyone lost on the first day.

First place in Sunrayce went to the University of Michigan's Sunrunner. Averaging 22.5 mph, the Michigan entry was the only one to finish all legs of the course under solar power.

Second place went to Western Washington University's Viking XX, with an average speed of 22.2 mph. Along with the Sunrunner and the Pride of Maryland, the Viking XX will be heading to the Australian race.

The Viking XX, featured on our August cover, was about the most radical vehicle we've reported on—until Associate Editor Stuart F. Brown got hot on the trail of this month's cover subject, *Earthwinds*. This 340-foot-tall lighter-than-air craft takes the look—and endeavor—of manned ballooning to unprecedented limits.

An update on another Earth orbiter, the heralded Hubble, tells us that the ripple effects from the star-crossed space telescope are likely to be far-reaching. Science and Technology Editor Arthur Fisher reports that coping with Hubble's trouble may cost $25 million a year and threaten the already tenuous plans to complete space station Freedom or embark on the manned Moon-Mars missions.

Finally, I direct your attention to two important environmental articles. In the Times Mirror Magazines Conservation Council report, you'll read how the Bush administration is tackling the issue of wetlands preservation and about action you can take to support this issue as the 1990 Farm Bill is considered in Congress. Also, in what's certainly the dirtiest job we've ever handed to a POPULAR SCIENCE writer, Associate Editor Mariette DiChristina has dug up some of the ways science and technology are waging—and winning—the war on garbage.

GAMMA LIASON: JOE KENNEDY

Michigan's Sunrunner scores a hometown victory.

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Readers Talk Back

1,000 words about a picture

You owe an apology to the makers of Friedrich room air conditioners for the cover and picture used for "Ozone-Friendly Cooling" [July]; they imply that those air conditioners leak chlorofluorocarbons into the atmosphere.

E. D. McGoun, Bryson City, N.C.

I was dismayed that your July cover was nothing more than an advertising coup for the Friedrich company. While the article was accurate, one photo or illustration in your magazine draws tremendous speculative interest. Also, you should have stated that today no room air conditioners—or central air conditioners—that use the new or experimental refrigerants are being commercially produced.

Philip J. Batterson
Technical Representative
Carrier Corp., City of Industry, Calif.

More on ozone-friendly A/Cs

Regarding "Refrigerators That Stay Cool Without CFCs," you said manufacturers are considering splitting the cooling system into two loops—one for the refrigerator and one for the freezer. Sun Frost has been making refrigerators with separate systems for eight years, as described in "Super-Fridge Can Run on Sunshine" [Nov. '85].

Larry Schlussler, owner
Sun Frost
Arcata, Calif.

Contrary to your article, the ozone hole was known about long before 1984. "Forty Years Research on Atmospheric Ozone at Oxford" appeared in Applied Optics (vol. 7, no. 3, 1968). In the article, G. M. B. Dobson, after whom the unit of measure for ozone concentration was named, described Antarctic ozone holes for 1956 through 1958.

Eli Lieberman, Silver Spring, Md.

Mistaken about wind power

In July's "RTB," a reader in favor of nuclear power states that "wind power's low-frequency vibrations cause health problems." As a consultant to the wind industry, I am unaware of any such health issue. Wind turbines do emit audio energy, but if you want to talk about damaging noise, big cities are a better starting place.

Michael D. Zuteck
Kemah, Texas

Quiet sub uncovered?

A submarine with a magnetohydrodynamic propulsion system would no doubt be quiet and difficult to detect by sonar ["Deep Cover," Aug.]. But wouldn't the MHD system emit an electromagnetic-field signature that could be tracked with magnetic-sensitive equipment?

Timothy E. Smith
Fredericksburg, Va.

The magnets in the MHD system would indeed create such a signature. However, it is possible to install shielding made from sheets of nickel-rich steel; this would absorb the magnetic field outside of the MHD system, reducing the risk of detection.—T. A. Heppenheimer

POPULAR SCIENCE 1989 index

To purchase the 1989 index, send $1.75 for one, or $1 each for five or more, to POPULAR SCIENCE Indexes, Box 2451, West Chester, Pa. 19380.

Corrections: The General Motors Willow Run, Mich., plant was originally built to make B-26 bombers during World War II ["Inside Saturn," Aug.].

The head-and-torso simulator dummy was developed and is manufactured by Bruel & Kjaer of Naerum, Denmark ["Science Newsfront," Aug.].

Address letters to Readers Talk Back, POPULAR SCIENCE, 2 Park Ave., New York, N.Y. 10016. Or fax your letter to us at 212-779-5468. We reserve the right to edit for space and clarity and cannot answer unpublished letters.

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Wetlands Conservation:
A National Priority.

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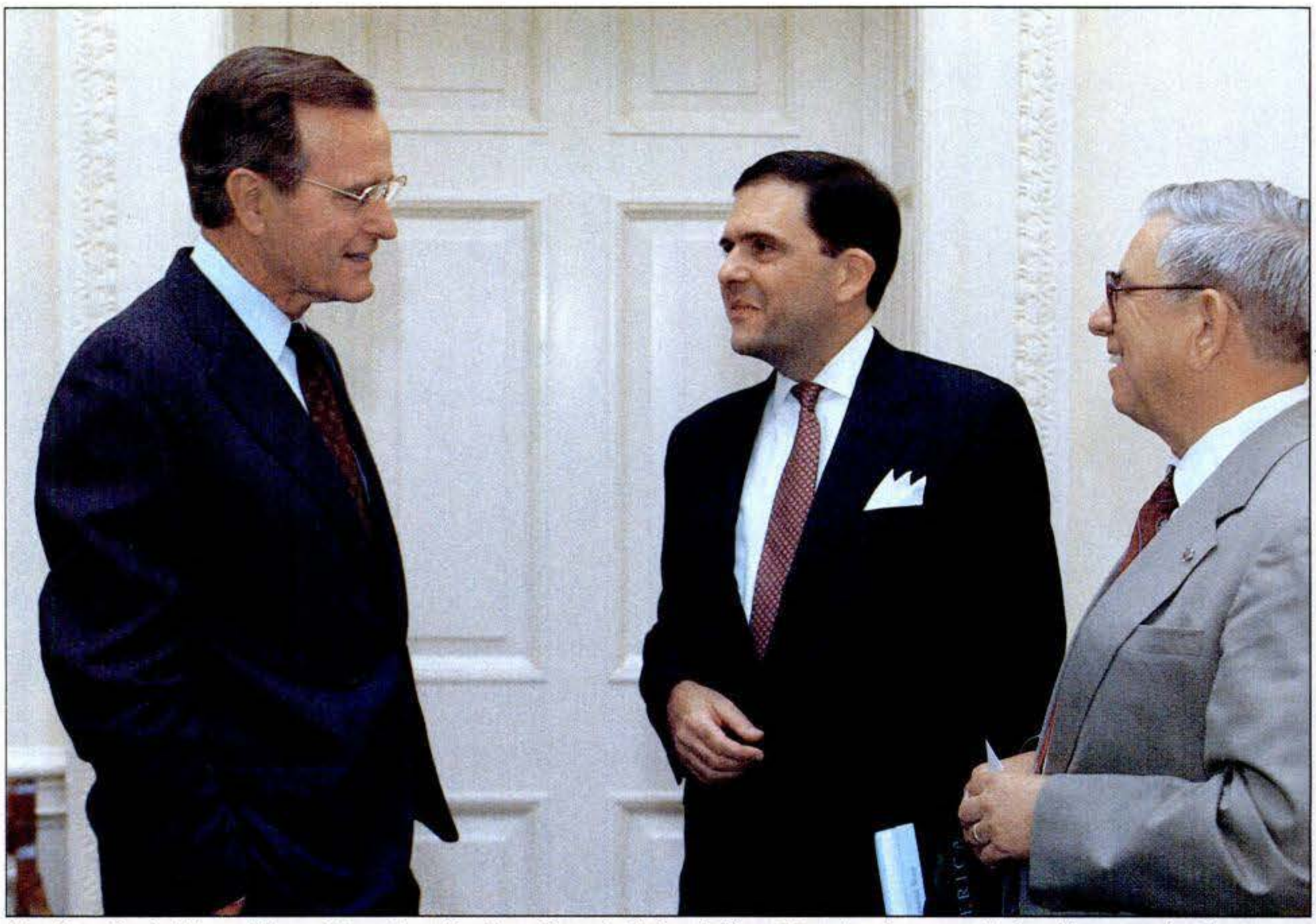


President Bush, Times Mirror Magazines President Francis P. Pandolfi and Interior Secretary Lujan discuss wetlands.

No Net Loss Of Wetlands

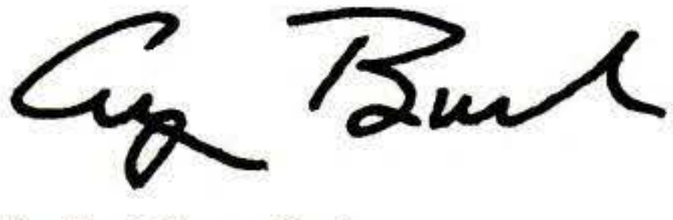
I am pleased to have this opportunity to address the readers of Times Mirror's magazines on a subject important to all of us—the environment. America enjoys the blessings of many natural riches—fertile soils, abundant water, productive fisheries, abundant wildlife, rich mineral resources, great forests and vast prairies.

As we work to preserve our precious environment, we must remember that this is one of the most important legacies we can leave for our children and grandchildren. They deserve nothing less than a healthy, safe and productive planet. My Administration is dedicated to an America—and a world— that is environmentally sound.

One area of continuing concern is our wetlands. I stand by my pledge to protect these critical areas of biological and ecological diversity by working toward a goal of no net loss of wetlands. We must strive to end the needless filling and draining of wetlands, and work toward the creation of new wetlands. A Wetlands Task Force, established through the Domestic Policy Council, is addressing this important issue.

I applaud programs such as those being pursued by the Times Mirror Magazines Conservation Council which seek to improve communication with the American people on conservation and environmental issues—including that of wetlands.

Individual citizens have a responsibility to do their part for our environment. Whether it's recycling paper, planting trees or protecting wetlands, everyone can make a difference. I hope the readers of Times Mirror's magazines will join in the effort to preserve for future generations the precious natural resources of our nation and our world.



President George Bush

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Wetlands: Critical Links in Natural Ecosystems

President Bush has pledged that his administration will perpetuate the many values we receive from wetlands. From a mountain bog feeding a sparkling stream to a tidal mangrove marsh, wetlands are an essential part of water-based ecosystems. Golf, skiing, fishing, boating, hunting and virtually all of the activities covered by Times Mirror's magazines generally rely on wetlands as a part of the supporting ecosystem.

Until recently, wetlands were not recognized as having a tangible value. Now we know that wetlands are homes and nursery grounds for fish and wildlife. They also store water, serve as buffers for erosion during flooding and act as natural filters of pollutants. They are critical links in the natural ecosystems that affect almost every facet of our lives.

However, in the recent past, agricultural and other subsidy programs existed to destroy wetlands; and they were quite successful, reducing 215 million acres of wetlands to 95 million acres. Recent data indicate an annual loss of 300,000 to 550,000 acres, resulting in changes in local weather patterns, severe declines in some duck and marine fish populations, and a lessening in the buffering capacity of natural systems to the effects of flooding, drought and pollution.

Over one-third of the almost 600 species of plants and animals that are threatened or endangered require wetlands for survival. When a species becomes extinct, a bit of diversity in our ecosystem is lost. With it goes part of an ecological safety net similar to the economic diversity that supports a healthy economy.

In 1985, Congress first woke up to the fact that agriculture is responsible for approximately 80% of wetlands destruction. So the 1985 Farm Bill included a provision called Swampbuster intended to encourage farmers to protect wetlands by eliminating the subsidies they receive if they produce crops on filled or drained wetlands. But the 1985 legislation was weak. Now, in the 1990 Farm Bill, improvements are being considered. First is a strengthening of Swampbuster to include better enforcement and the loss of eligibility for federal subsidies upon conversion of a wetland, rather than after a commodity crop is planted on it.

The proposed 1990 Farm Bill also includes a Wetlands Reserve Program, where farmers would be paid to permanently protect the wetlands they put in this Reserve. Congressional proposals for the total acreage under this program range from one to five million acres.

Backers of these improvements in the Farm Bill believe the public, which is expected to pay farmers $50 to $75 billion in subsidies over the next five years, should receive a benefit in the form of the conservation of natural resources. Opponents to Swampbuster want farmers to receive public cash with as few strings attached as possible. Although no subsidies might be best, wetlands protection often costs the public less than crop subsidies. Much of the draining and filling of wetlands on farms has been to produce crops that are eligible for subsidies.

In September 1990, the House and Senate should be in conference working out differences in the bills from each body. So there still exists opportunity for you to influence the protection of wetlands in the 1990 Farm Bill.

Additional legislation to protect wetlands exists in the 101st Congress such as the Fish Resource Conservation Bill to establish The National Fishery Resource Conservation System for protecting, managing and acquiring priority fisheries habitat. Also, the Coastal Zone Improvement Act will encourage states to protect coastal wetlands. However, legislation is not the only way to protect wetlands. Both the U.S. Fish and Wildlife Service and the Bureau of Land Management have new strategies to protect and restore the wetlands they manage.

In every conservation issue, a balance must be found between outright preservation of all that is natural, and the needs of our citizens. Responsible development and multiple use of natural resources must involve a long-term outlook of maintaining natural resources rather than taking the short-term payoff of drain and fill.

ACTION YOU CAN TAKE

Congressmen and Senators want to hear most from the voters back home, the people they are paid to represent, the ones who put them in office. Here's how you can make a difference:

To express your support for a strong conservation section in the Farm Bill and the other legislation to protect wetlands, write your elected officials: The Honorable (Name), United States Senate (or) House of Representatives, Washington, D.C., and the Senate's 20510 zip code or 20515 for the House.

To learn about or support the Bureau of Land Management (BLM) and the U.S. Fish and Wildlife Service (USFWS) wetlands programs write: BLM Director Cy Jamison and/or USFWS Director John Turner. Both are at the Department of the Interior, Washington, D.C. 20240. You should also write to the President's Wetlands Task Force in room 5138 at the U.S. Fish and Wildlife Service.

Times Mirror Magazines, publisher of this magazine, has launched an aggressive conservation program. Comments from our readers help guide our program. Write: Dr. David Rockland, TMM Conservation Council, 1705 DeSales St., N.W., Washington, D.C. 20036.

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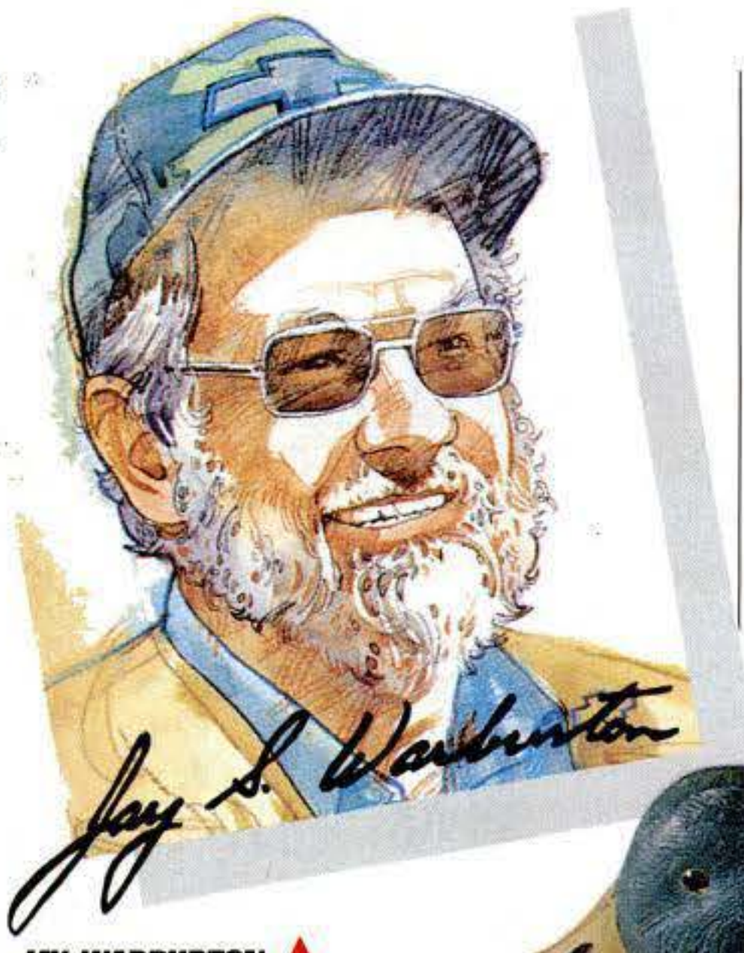
Wetlands and Conservation: A



JAY WARBURTON ▲

President, Home Video Network (HVN); national award-winning outdoor writer and film producer. Member Chevy Truck Outdoor Pro Team.

The wise use of our natural resources.

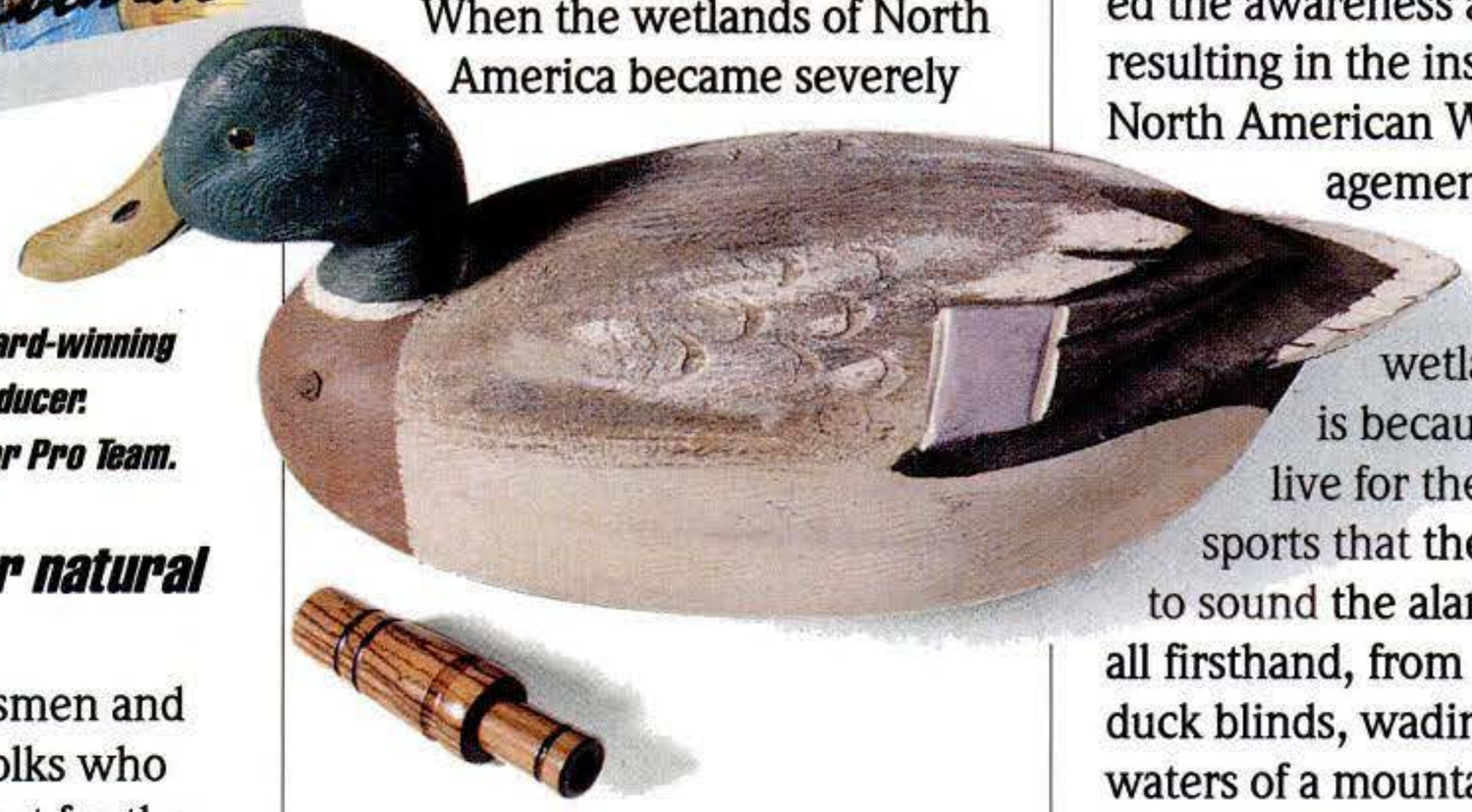
The true outdoorsmen and women of today are folks who have the utmost respect for the conservation of those natural resources which Mother Nature has provided.

Since the birth of modern-day wildlife management programs just over a century ago, the wise use of our natural resources has become a way of life for all those who enjoy and respect the sports associated with our renewable wildlife and fishery resources.

Throughout this country, active sportsmen have continuously been the leaders in the ongoing challenge of assuring that the grand beauty of the outdoors is maintained and expanded in value, to guarantee that the grandeur of nature's wealth will be there for generations to come.

Ducks Unlimited, Inc. A powerful force for conservation.

When the wetlands of North America became severely

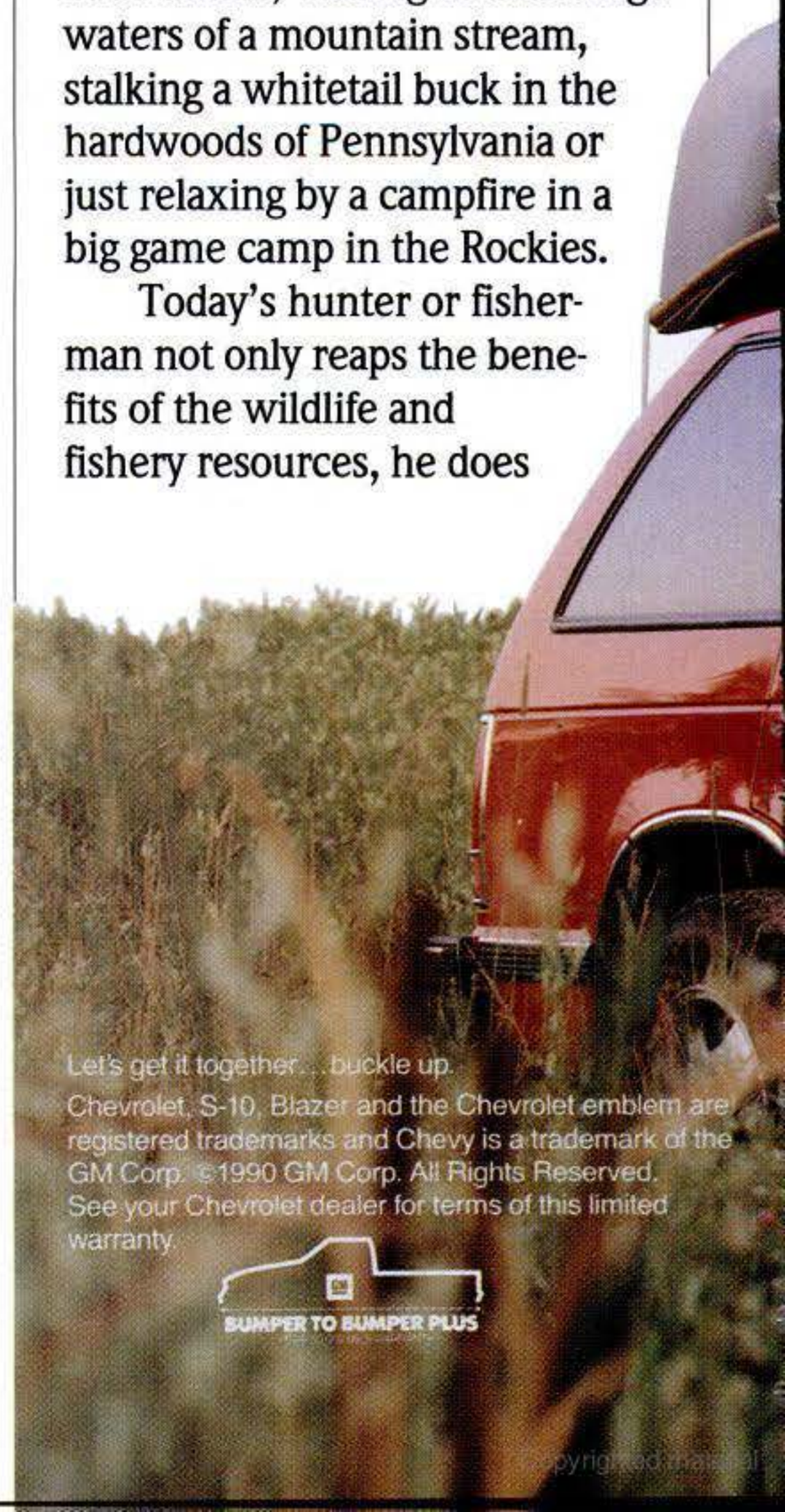


threatened in the 1930s, Ducks Unlimited, Inc., was formed by a handful of concerned sportsmen. It now boasts an active membership of over a half-million who have contributed millions of dollars and volunteer hours. Started by waterfowl hunters, Ducks Unlimited, Inc., has resulted in the protection of millions of acres of wetlands which provide permanent habitats for large and small game, waterfowl, fisheries and many non-game species.

Wetlands and today's sportsman.

As it has been in the past, today's sportsmen and women are the leaders in promoting the wise use of all our natural resources. The sportsmen's concern about the dwindling wetland resources and the decline in waterfowl population has provided the awareness and the dollars resulting in the institution of the North American Waterfowl Management Plan and President Bush's "no net loss" of wetlands program. It is because sportsmen live for the love of their sports that they are the first to sound the alarm. They see it all firsthand, from snowblown duck blinds, wading in chest-high waters of a mountain stream, stalking a whitetail buck in the hardwoods of Pennsylvania or just relaxing by a campfire in a big game camp in the Rockies.

Today's hunter or fisherman not only reaps the benefits of the wildlife and fishery resources, he does


Let's get it together... buckle up.
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See your Chevrolet dealer for terms of this limited warranty.
BUMPER TO BUMPER PLUS

Heritage for America's Future.

so with the knowledgeable respect, concern and dedication to the health and future preservation of the wilds which he has learned to love.

Chevy S-10 Blazer 4-Door: It takes to wetlands like a duck to water.

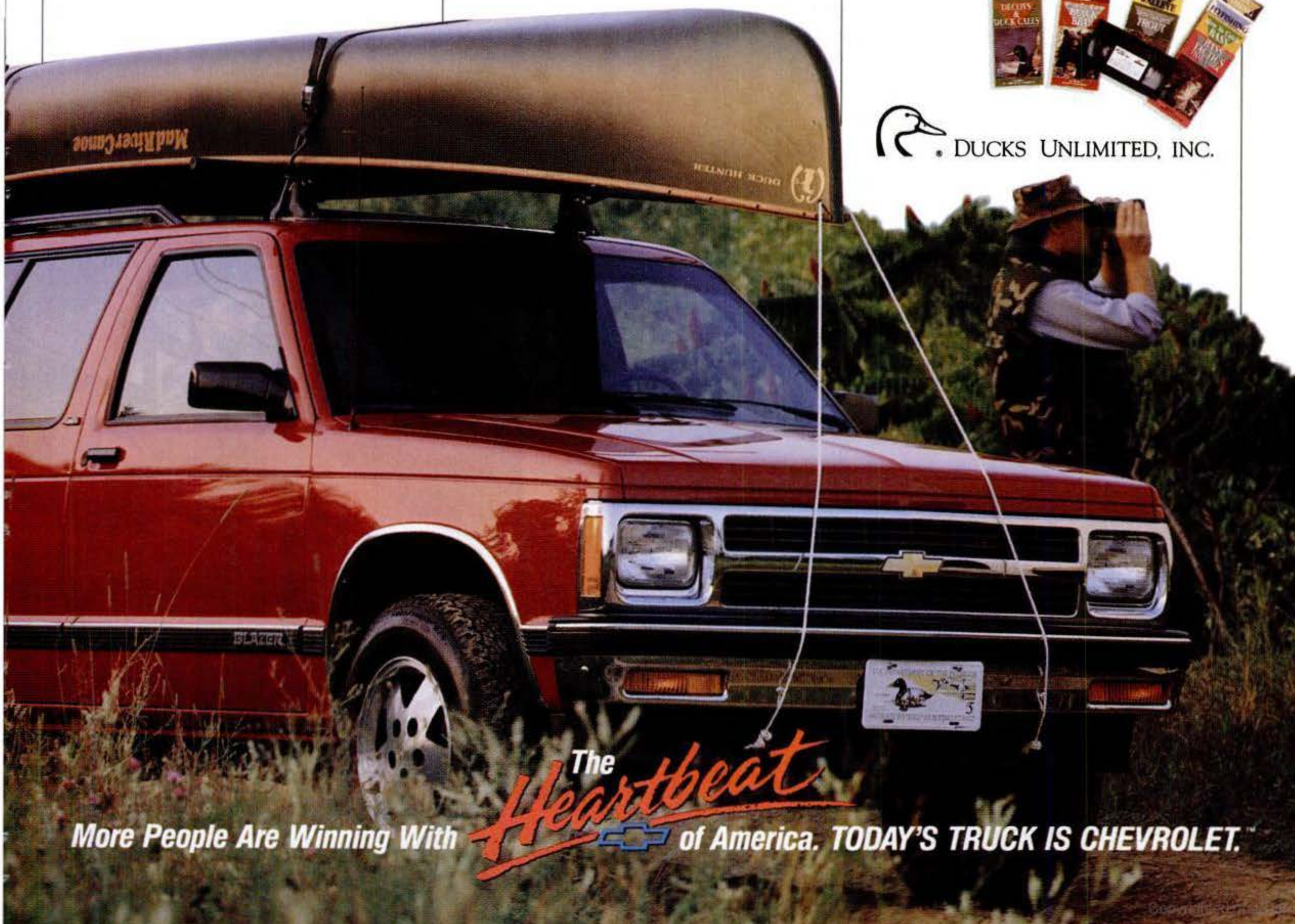
America's best-loved sport utility vehicle just got bigger. In a new 4-door model. With 25% more cargo room behind the rear seat. And available seating for six.

Shift-on-the-fly Insta-Trac™ is America's most popular 4-wheel-drive system. Coupled with the biggest V6 you can get, the 4.3L Vortec V6, it gives you plenty of towing ability and off-road power. Chevy S-10 Blazer's perfect for today's sportsmen.

Sportsmen's Workshop Video Library.

In the Sportsman's Workshop Video™ Library, tips and insight will be provided for outdoor sports ranging from bass fishing to ducks and decoys to big game hunting. Every time you buy one of these videos with the Ducks Unlimited logo, a portion of the purchase price will be used to protect wildlife habitat. Thanks to Chevy sponsorship, these videos are only $9.95. Videos are available at better retailers nationwide or may be ordered direct by calling 1-800-223-3428.

DUCKS UNLIMITED, INC.



The Heartbeat of America.

More People Are Winning With TODAY'S TRUCK IS CHEVROLET.™

BY JUDITH ANNE YEAPLE

What's New

◀All eyes and ears

This prototype combat robot uses video cameras and acoustic monitors for surveillance work while the operator is a safe two miles away. A fiber-optic data link lets the operator and robot communicate. The robot was designed for Sandia National Laboratories by Grumman Corp.

Snooping bagel▼

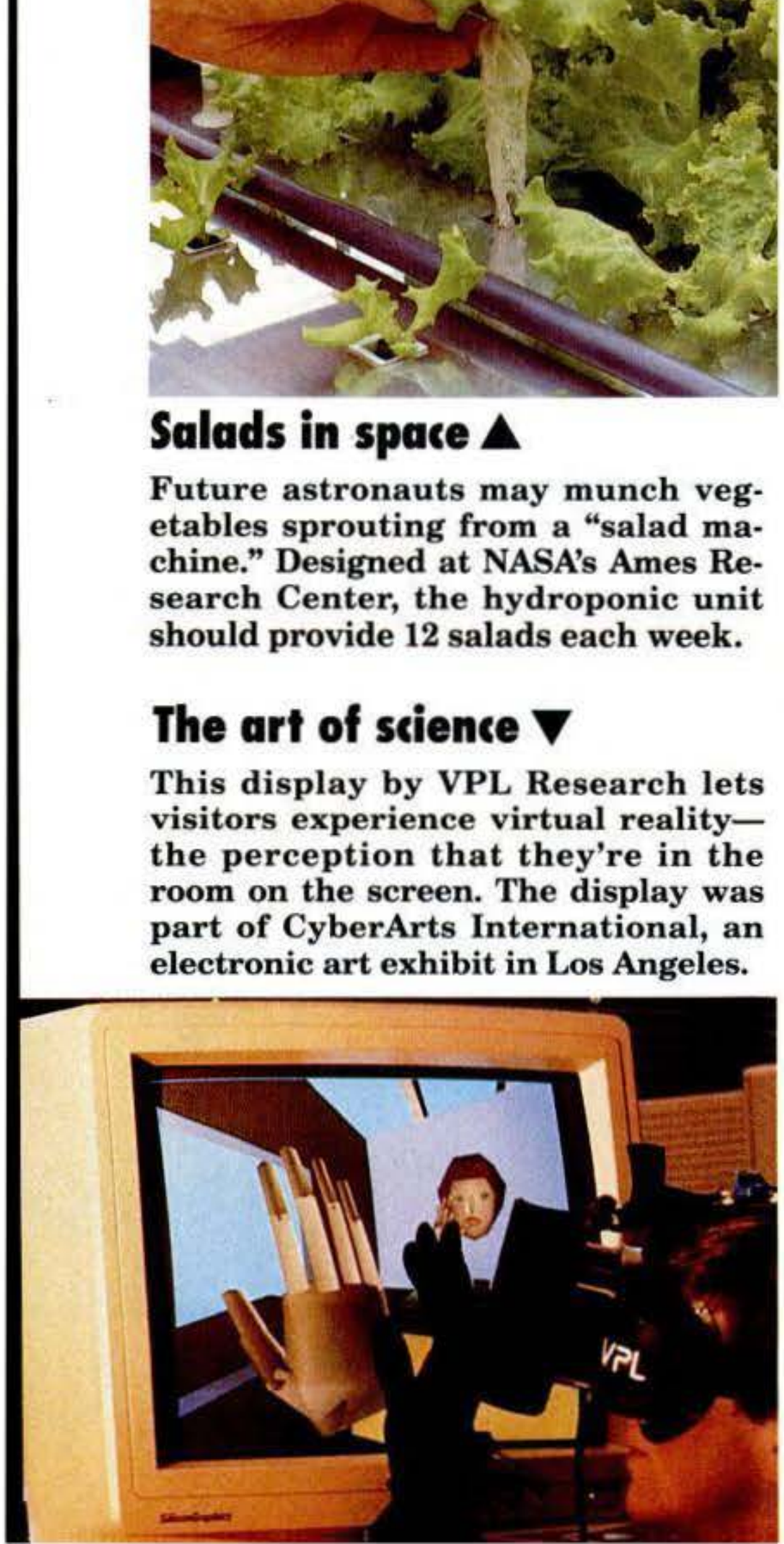
Whether aiming its video cameras at enemy targets or rush-hour traffic, this unmanned aircraft can hover over a position for hours. The six-foot-diameter Cypher cruises at 80 knots and at altitudes up to 8,000 feet. Sikorsky designers say enclosing the counterrotating blades minimizes the danger to ground personnel.

Salads in space ▲

Future astronauts may munch vegetables sprouting from a "salad machine." Designed at NASA's Ames Research Center, the hydroponic unit should provide 12 salads each week.

The art of science ▼

This display by VPL Research lets visitors experience virtual reality—the perception that they're in the room on the screen. The display was part of CyberArts International, an electronic art exhibit in Los Angeles.



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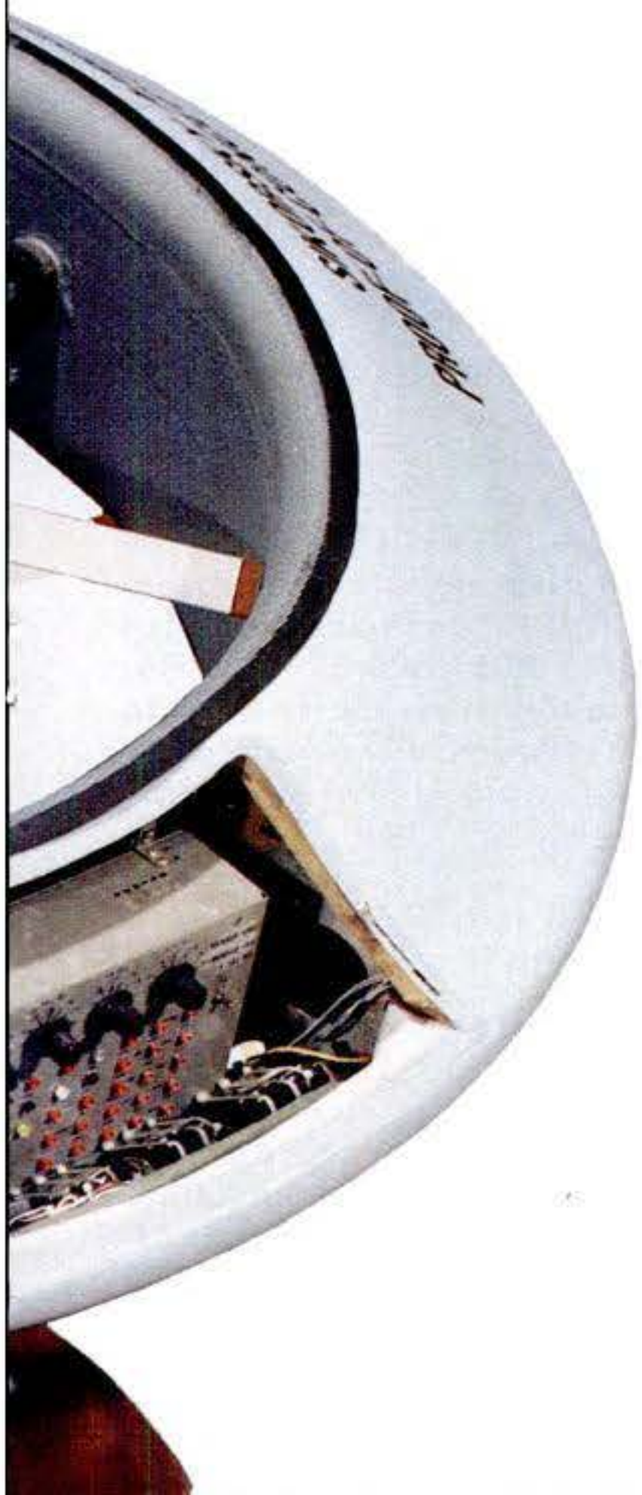
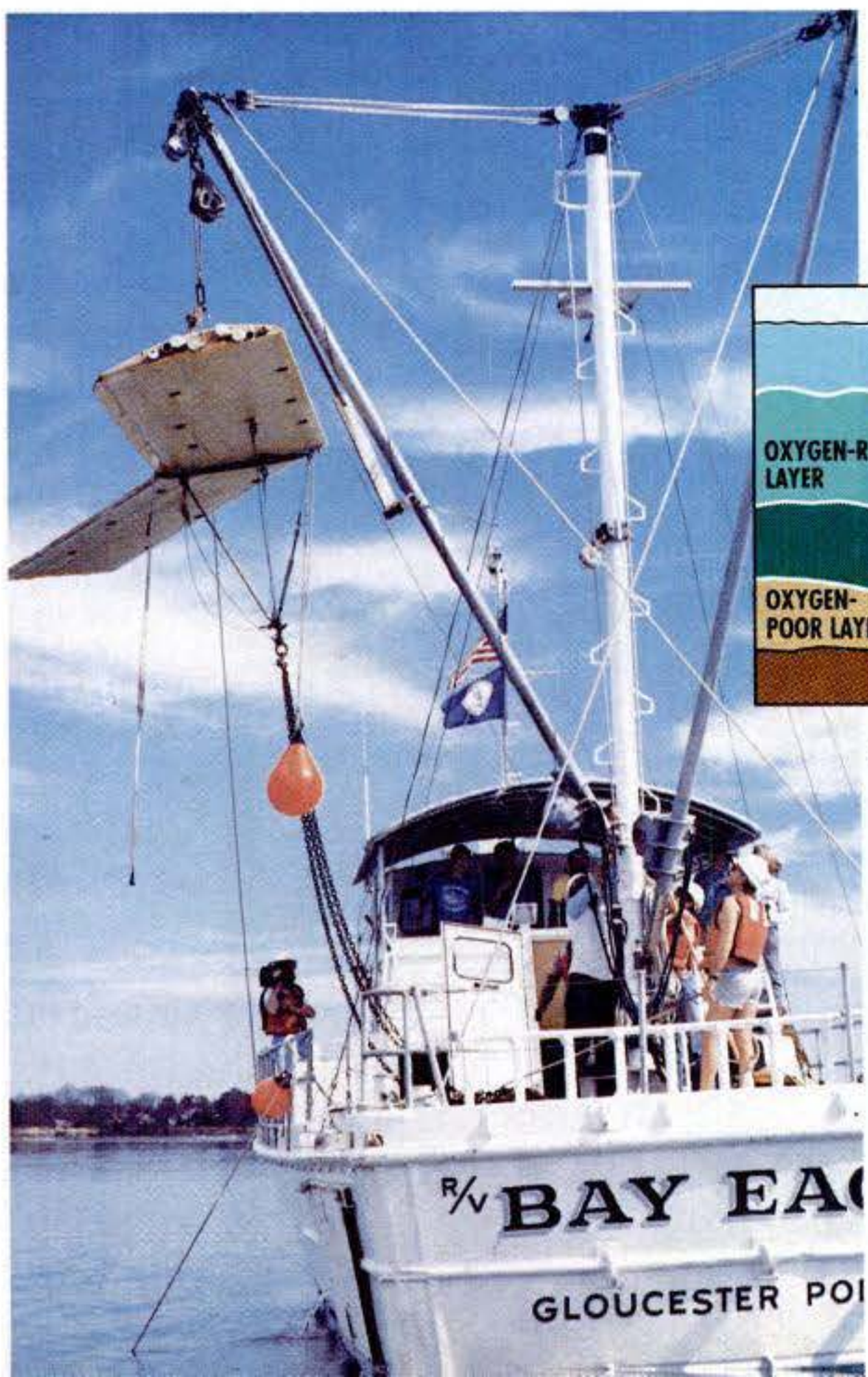
Truss test ▲

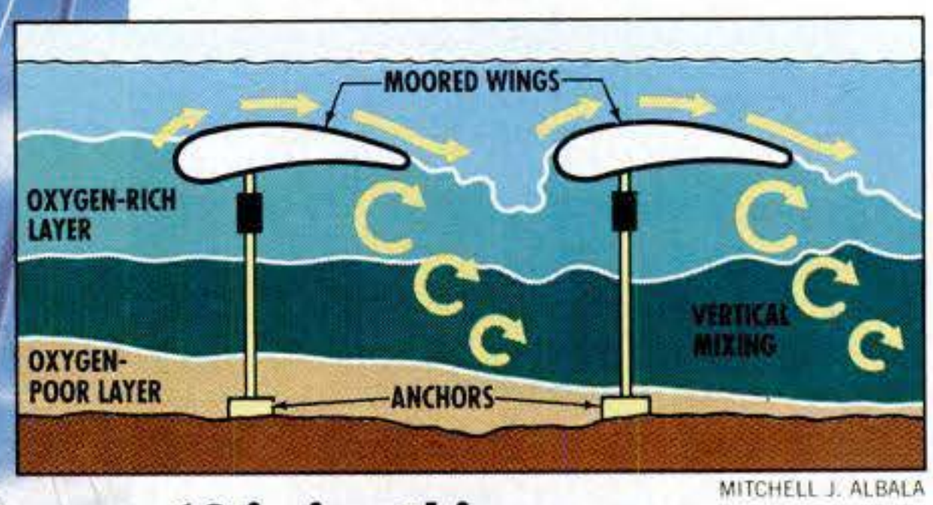
Wright-Patterson Air Force Base engineers tested this 300-pound flexible truss in simulated zero gravity to determine its behavior in space. The truss was stowed in a plane that flew parabolic maneuvers, creating 25-second intervals of weightlessness. The results will help them design large, flexible space structures.

"Green" skyscraper ▶

Poland's proposed 70-story Warsaw Trade Center will be made of a recycled aluminum skin and concrete that includes World War II rubble. Solar-powered lights will illuminate the spire. American architect William McDonough also wants 10 square miles reforested to compensate for its ecological damage.







MITCHELL J. ALBALA

◀ Stirring things up

Scientists at NASA Langley Research Center and the Virginia Institute of Marine Science used aviation technology to design a "water wing" to mix oxygenated water into the deeper, oxygen-poor regions of the Chesapeake Bay. Anchored four feet above the bay bed, the 20-foot-long wing creates vortices as the current streams around it. Currently tested in the York River, the project will foster regrowth of aquatic life.

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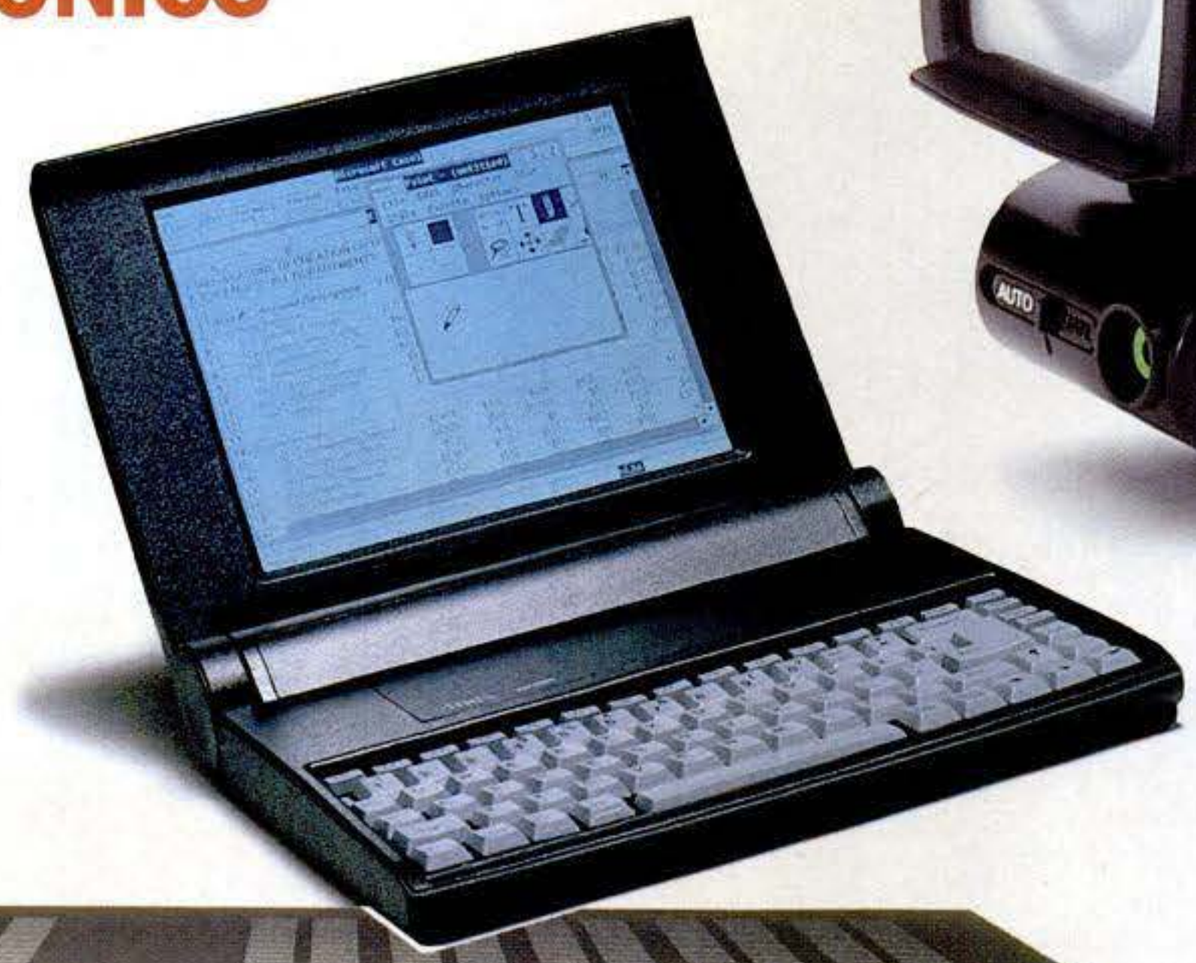
BY WILLIAM J. HAWKINS

What's New ELECTRONICS

Lap-top ▶

Airis's computer is six pounds of power: an 80286 processor, an 11-inch VGA LCD, a 20-megabyte hard disk, two megabytes of RAM, and a 2,400-bps modem. The VH-286 is priced at $1,899 from Airis Computer Corp. (1824 N. Besley Ct., Chicago Ill. 60622).



Just the right light ▲

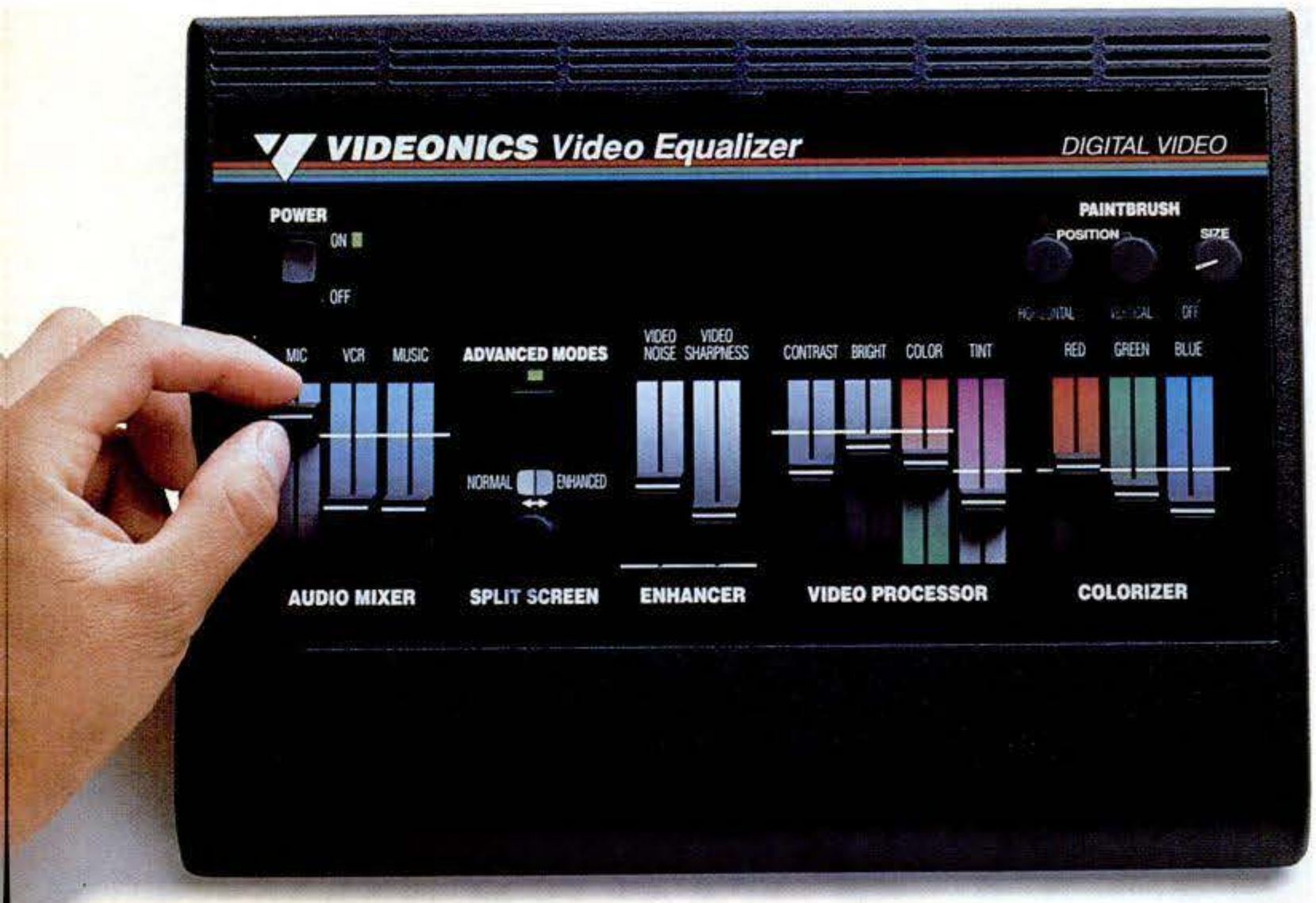
Not enough light, and your home videos are impossible to see. Too much, and they're washed out. That's why the CV-20SA camcorder Video Light uses photocells to determine room lighting and adjust its output from 7 to 20 watts for the right balance, according to the maker, Sunpak/Tocad America (401 Hackensack Ave., Hackensack, N.J. 07601); $150.

Perfect picture ▲

Toshiba's TRX-2000 is the first satellite TV receiver to have an S-Video output. The special connection, for both Super-VHS VCRs and S-Video-equipped monitors, keeps video and color information separated, significantly reducing dot crawl, smears, and color bleeds in the picture. The LCD display shows antenna position and satellite information; $1,949.

Two-way VCR ▲

Make a video on a compact VHS-C camcorder, and you can't use the cassette on your home VCR without a special adapter. No longer. JVC's new F/C-compatible HR-SC1000U VCR uses a new loading mechanism to accept either full or compact cassettes for recording or playback. The Super-VHS machine records with up to 400 lines of resolution, comes with a jog/shuttle remote, and is programmable for up to 20 events; $1,599.



◀ Digital editor

Edit your home videos with the Video Equalizer and its digital circuitry lets you change the color of elements in a scene—from the tie you wore to the color of the house in the background. Overall color, contrast, and brightness can be changed as well. It's $300 from Videonics (1370 Dell Ave., Campbell, Calif. 95008-6604).

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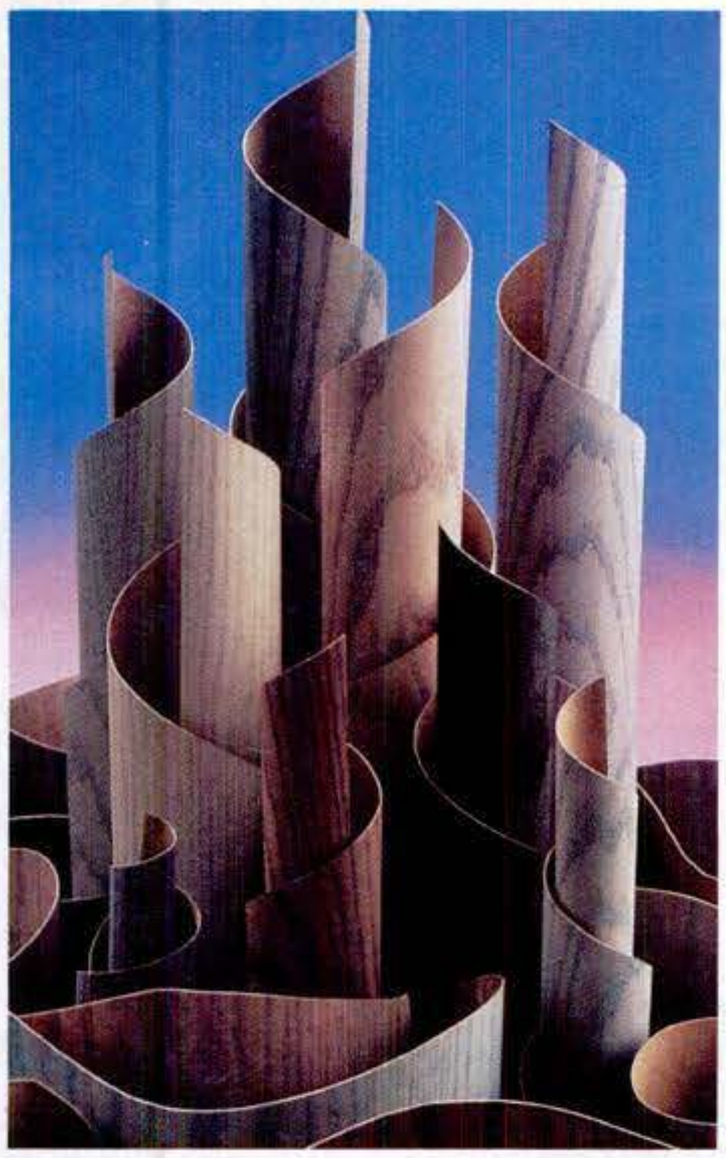
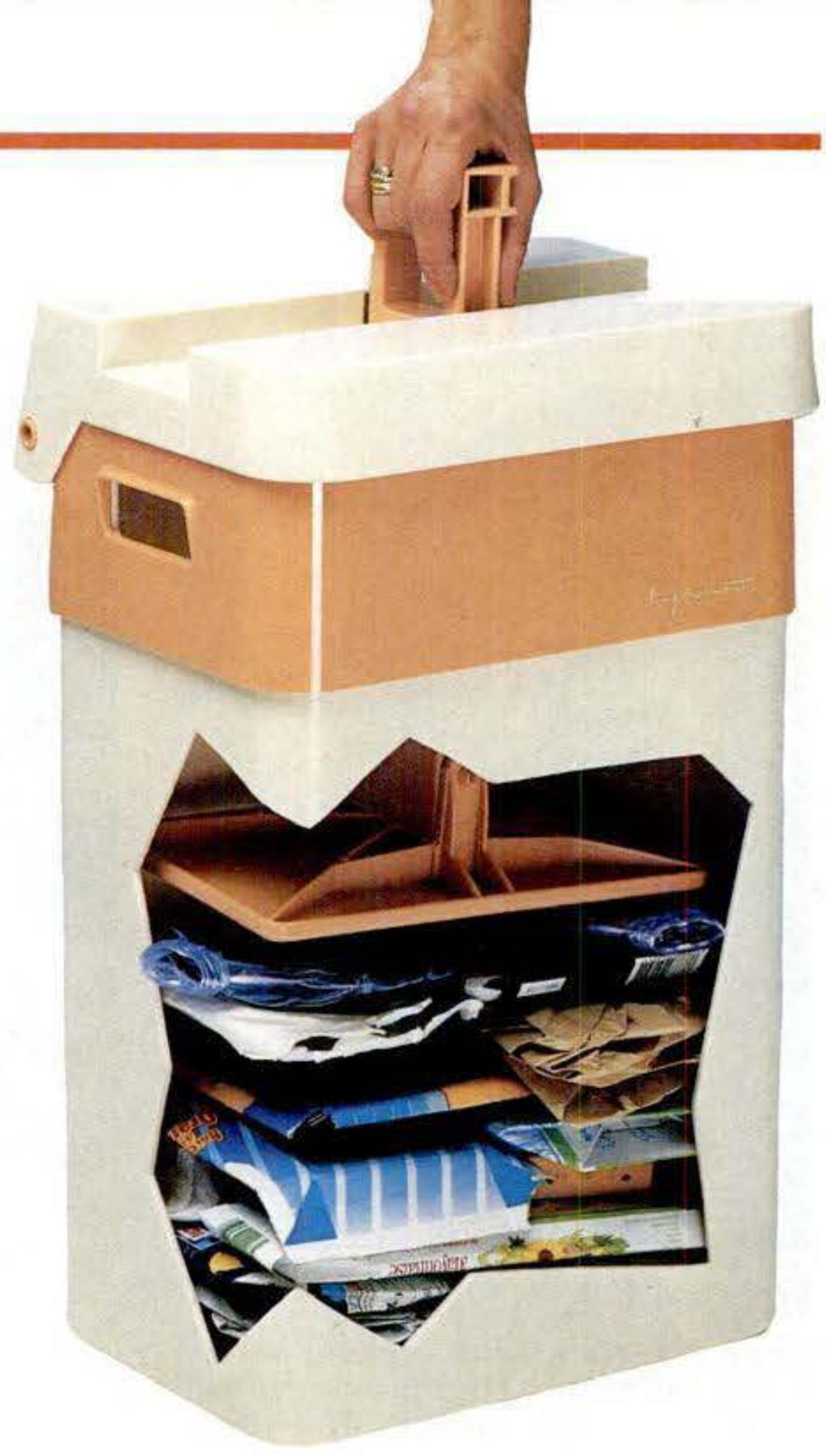
BY MARCELLE M. SOVIERO

What's New HOME



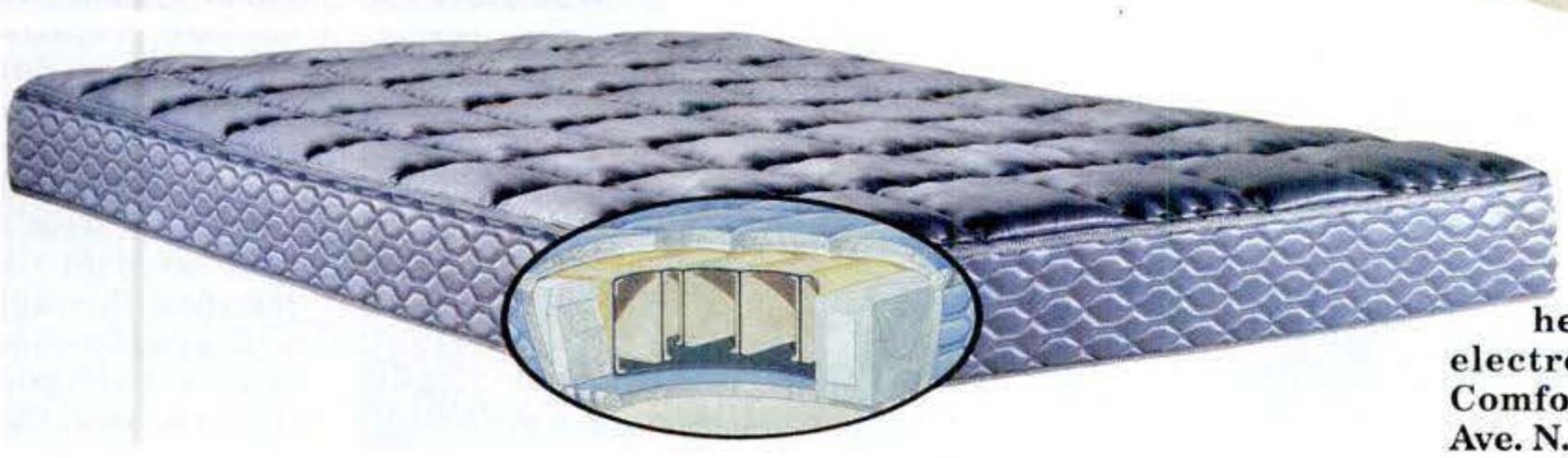
Garbage cruncher ▶

Tired of taking out the garbage? You won't have to do it as often with the Compac trash can, which holds three to four times more garbage than other bins its size. The hinged lid serves as a manual compactor—just swing the handle upright then down against the pressure plate for periodic compacting. Compac Manufacturer, 5321 Cleveland St., Suite 201, Virginia Beach, Va. 23462. Price: $40.



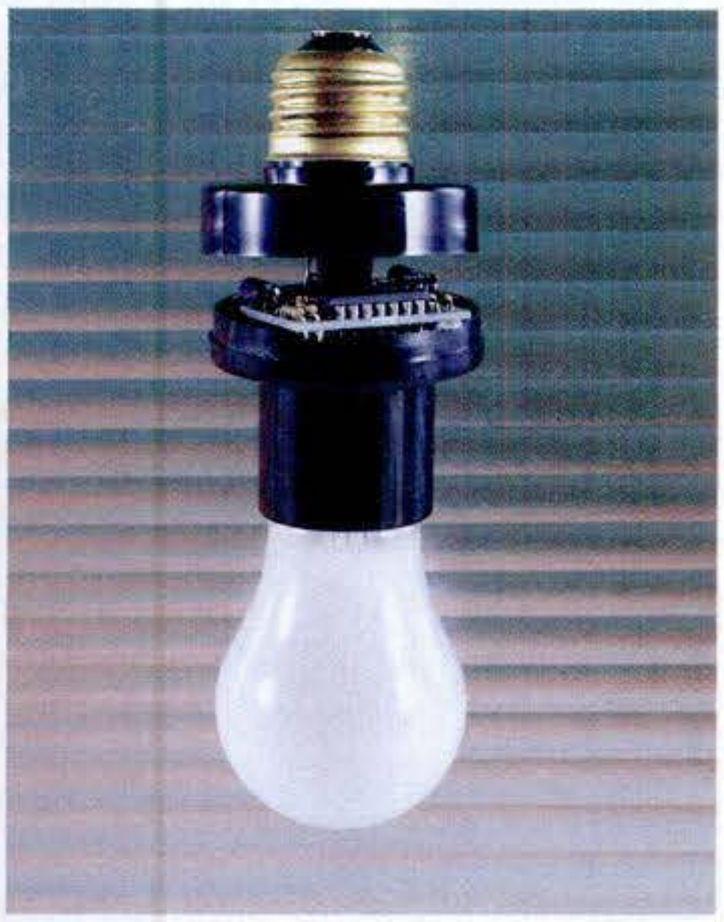
◀ Tinted wood veneer

Need a match for your wood cabinets? Craftwood Color Tinted Veneers come in 12 pretinted cut oak styles or can be custom-made in virtually any color or neutral stain. The veneers are available in sheets with laminate or paper backers. Ralph Wilson Plastics, 600 General Bruce Dr., Box 6110, Temple, Texas 76503.



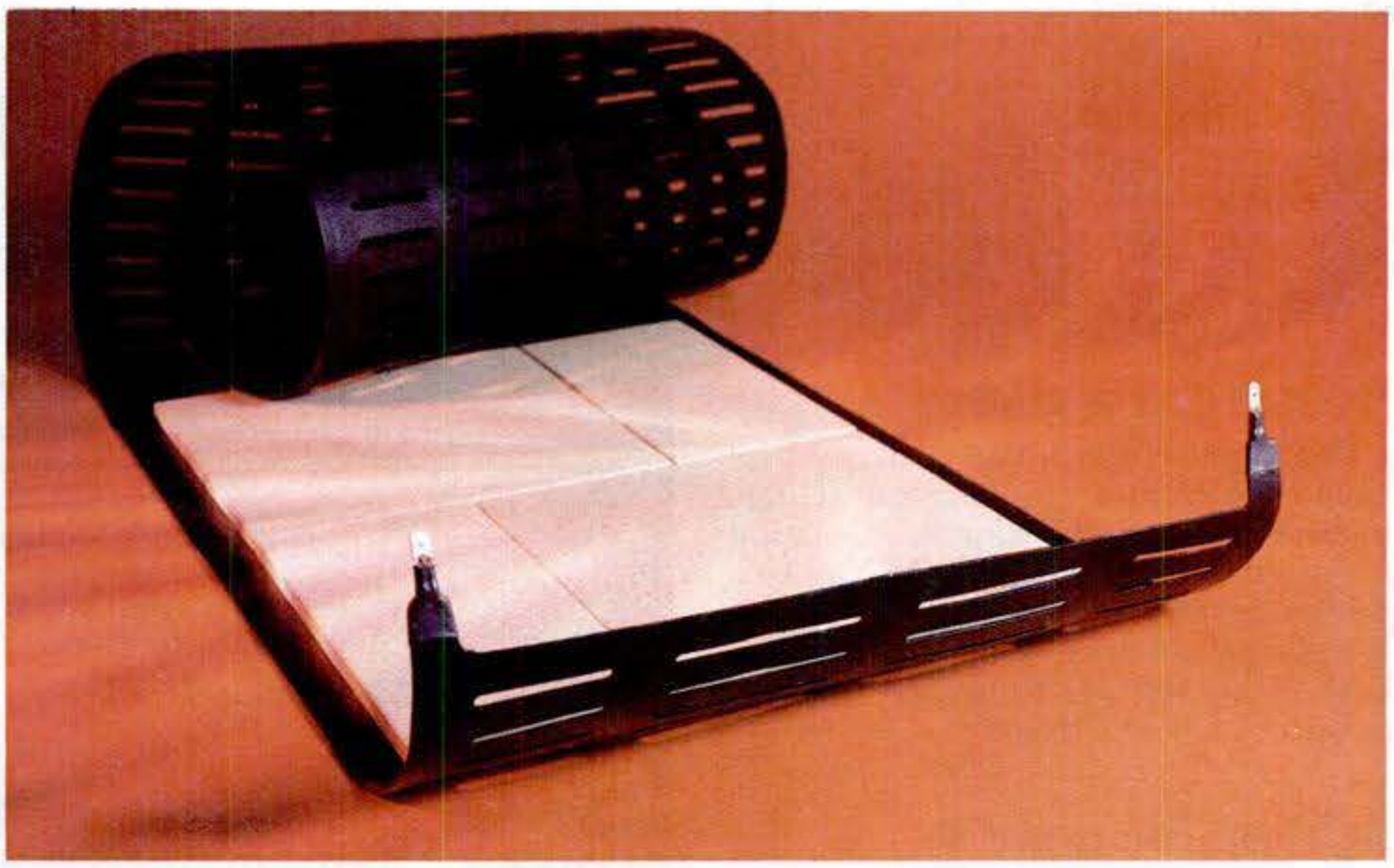
◀ Adjustable mattress

A dual air-chamber system inflates and deflates the Select Comfort mattress with the push of a button on a handheld control. This activates an electronic air control unit. Select Comfort Sleep Systems, 11010 89th Ave. N., Minneapolis, Minn. 55369.



Emergency porch light ▲

In an emergency, you can turn your porch light into a flashing beacon. Just screw the adapter in between the bulb and its socket. To activate the system, flip the switch twice. Consumer Engineering, 1240A-4 Clearmont St., N.E., Palm Bay, Fla. 32905.



Plastic radiant floor heating system ▲

Unlike other radiant floor heating systems that use metallic conductors sandwiched between plastic sheets, the Electroplastic system is made from solid carbon polyethylene. It also needs no thermostat; as the temperature rises, the current draw falls until the system reaches its operating temperature, about 85 degrees F. The mats have adhesive strips for easy installation and are suitable to warm up areas such as bathroom floors, says Electroplastic Heating System (1456 Second Ave., Suite 204, New York, N.Y. 10021).

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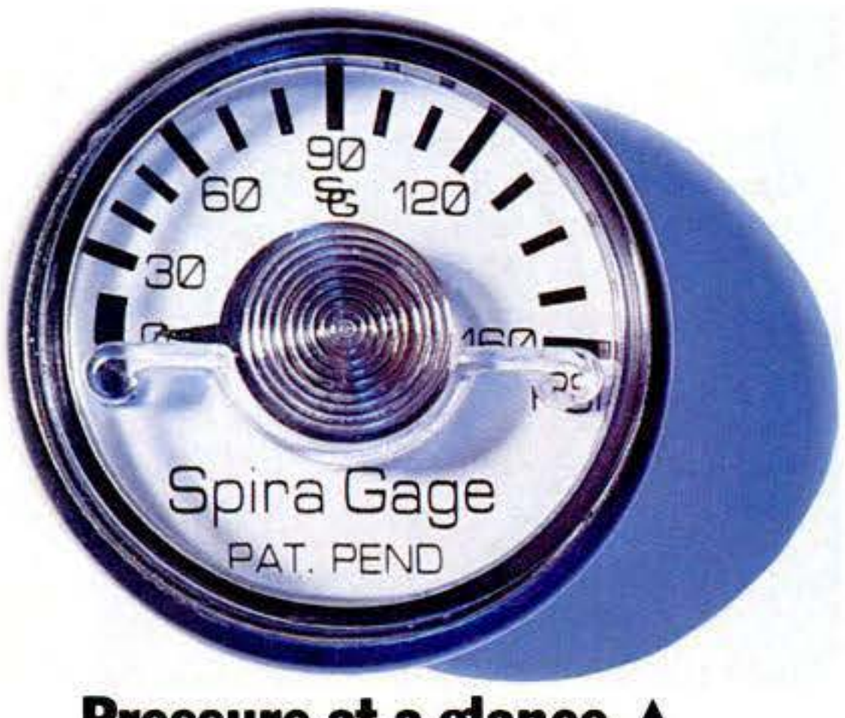
BY BRIAN NADEL

What's New AUTOMOTIVE

Hot seat ▲

Tired of getting into a cold car seat on winter mornings? The Plastelektro self-regulating seat heater is the Norwegian solution to cold buns. The flexible element warms any seat and uses only 15 watts of power, according to Plastelektro (Handverkergaten 4, N-3100 Tonsberg, Norway).

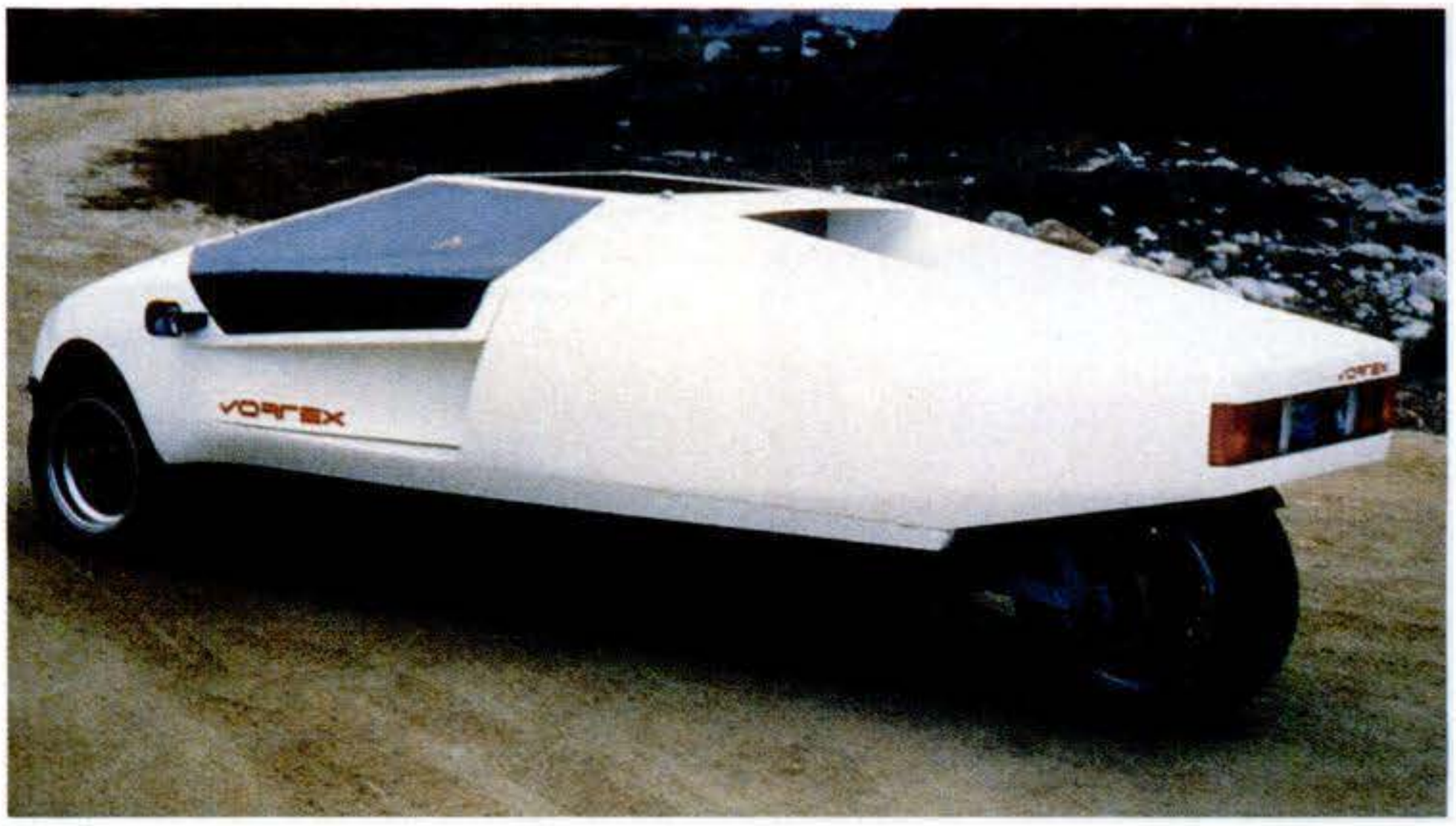


Pressure at a glance ▲

A tire's pressure level can now be checked with just a look at SpiraGage, the first on-wheel tire gauge, according to United Instrument (Box 20626, Portland, Ore. 97220). At $10 per wheel, SpiraGage accurately reads pressure from 60 to 160 psi to ensure proper inflation of truck tires.

Light up the night ▶

The brighter line on the left is painted with Visibead safety marking spheres four to five times larger than those in the conventionally painted line to the right. The manufacturer claims it reflects light 2½ times better than other lane markings. Potters Industries, Waterview Corporate Centre, 20 Waterview Blvd., Parsippany, N.J. 07054.



Foam and fiberglass motor trike ▲

The angularly styled urethane foam and fiberglass Vortex three-wheeler is powered by an 82-hp 750-cc Kawasaki motorcycle engine. It has a pair of steerable front wheels and a single rear drive wheel. Plans cost $30 from Dolphin Vehicles (1270G Lawrence Station Rd., Sunnyvale, Calif. 94089).

◀ Antifreeze reclaimer

Instead of throwing away spent automotive coolant, mechanics can now reclaim and reuse ethylene glycol antifreeze with Cool'r Clean'r. The coolant is pumped through a 10-step filtration system. Then positive and negative ions are removed to bring it back to the original specs. BG Products, Box 1282, Wichita, Kan. 67201; $8,490.

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More mus

The new mid-size Dodge

More payload than standard Ford and Chevy half-tons.

There's a new truck on the street that's muscling its way into the hearts of serious truck drivers. Its agility approaches compacts. Its payload capacity holds its own against meatier half-tons. And with the available power of a V-8, it becomes the best all-around pickup on the road today. It's the new mid-size Dodge Dakota.*

We revved up our Dakota with a 170 HP V-8.

Flexes new V-8 muscle.

To any skeptic who thinks Dakota's a dressed-up compact, take a look under the hood. There you'll find a choice of hard-working engines including our 5.2L V-8 and 3.9L V-6–something no compact pickup can offer.

Plenty of workout room – with 6½' and 8' beds.

The V-8 delivers 170 hp at 4,000 rpm and 262 lbs-ft of torque at 2,400 rpm. Equipping you with the power you need–on the freeway or on the job.

Equipped for heavy loads.

If you want to see what a Dakota can carry, fill it up with a load of topsoil. We've got up to 2,550 pounds of available payload, depending on engine and model. A standard Chevy half-ton can't haul as much. Neither can Ford. And although it's 500 pounds lighter than the Chevy C1500, Dakota can actually carry 300 pounds *more*.** Not bad for a truck that's a lot leaner than its full-size competition.

The body you always wanted.

Dakota also stands up to

Dodge Dakota 4x4 Sport

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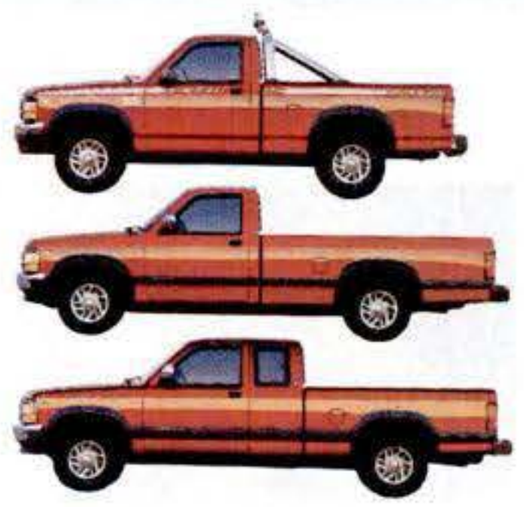
cle, less fat.

Dakota. Now with V-8 power.

full-size pickups when it comes to versatility, too. With three-across seating and more legroom on the inside. And a choice of six-and-a-half and eight-foot cargo beds out back. Dakota performs, whether you're trucking around eight-foot sheets of plywood or an eight-foot pool table.

Dakota body styles are equally impressive. And every one of them has been restyled for 1991. So take your pick. From 4x2, 4x4, Club Cab and Sport models. With options like air conditioning, a chrome rear step bumper and 22-gallon fuel tank, available at special Advantage Package savings.†



Bodies of all sizes and shapes: 4x4, 4x2 and Club Cab.

parallel parking space, Dakota is a perfect fit.

You'll also be glad to know that no matter how hard you are on your truck, there's something even tougher–our exclusive 7/70 Protection Plan. It covers the powertrain for 7 years or 70,000 miles and against outer body rust-through for 7 years or 100,000 miles.††

The agility you always needed.

Dakota beats full-size pickups in one more crucial area: maneuverability. Whether you're fighting your way to a loading dock or squeezing into a

Welcome home to Dodge.

America is coming home to Dodge. For the power of our mid-size Dakota V-8. For our full-size Cummins Diesel, the only full-size turbo diesel pickup you can buy. And we think they've come home to stay. Come see what we're made of.

*Competitive claims based on '90 data ('91 competitive data incomplete at time of printing). **Available regular cab 4x2 payload comparisons. †Package savings based on list prices of Advantage Package items if sold separately. ††See this limited 7/70 powertrain and 7/100 outer body rust-through warranty and restrictions at your dealer.

Buckle up for safety.

Advantage: Dodge.

Dodge

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BY MARIETTE DiCHRISTINA

What's New TOOLS

More gripping than ever ▲

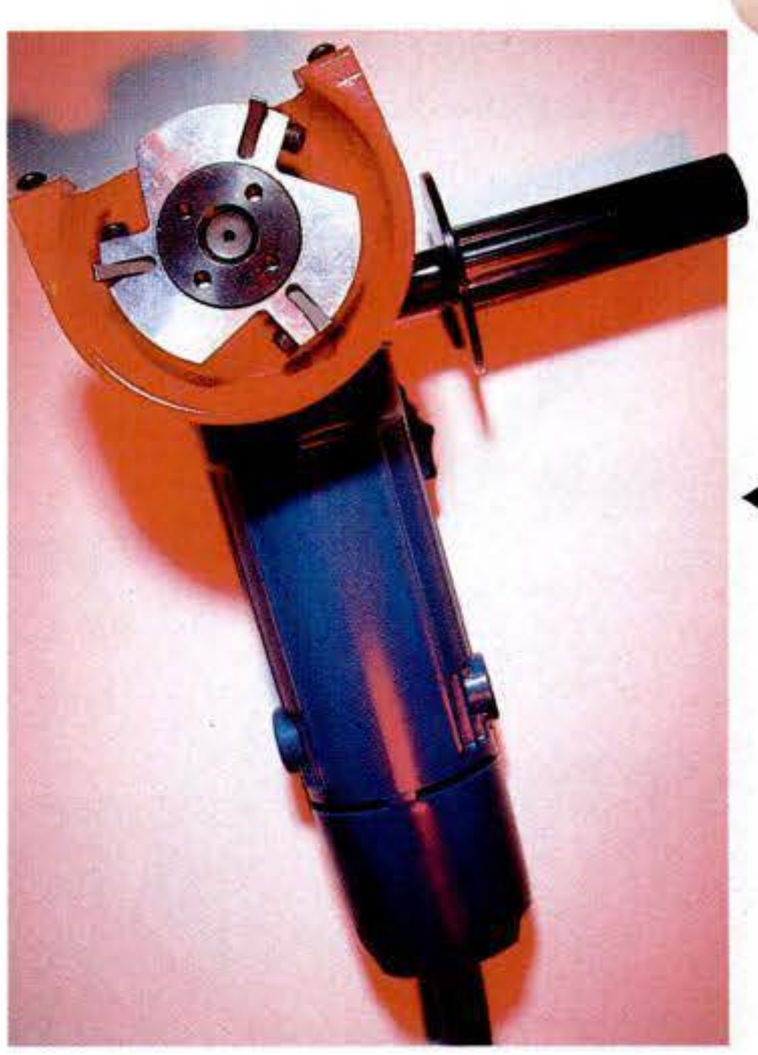
With a $30 accessory kit, the Quick-Grip bar clamp [Aug. '89, Dec. '89] becomes more versatile. The kit has two six-inch throat clamps and two sets of slide-on jaw pads: 3 1/4-inch pads to hold wider work and "V" pads that turn Quick-Grip into a miter clamp. American Tool Companies, Box 337, DeWitt, Neb. 66341.

Dripless painting ▼

The cordless Power Brush Painting System evenly lays on a quart of color without stops to dip, says the maker. Flow adjusts with a button. The $40 system uses two D cells. Wagner Spray Tech Corp., 1770 Fernbrook Lane, Minneapolis, Minn. 55447.

◀ Help for tight spots

This squeeze-action ratchet wrench helps when you have little room to maneuver: Pump the grip, and a cam-and-link mechanism turns the socket hex shaft. The rotation is reversible, as with a standard double-sided ratchet wrench. Colin Reeves, 9 Severn Way, Apperley, Gloucestershire GL9 4DA, England.



◀ Zip it off

The three-sided carbide blades of the Paint Shaver spin at 10,000 rpm to strip old paint from wood clapboards and shingles at a rate of more than one square foot per minute. In our tests the scraper was faster than a flat sander, but left the surface rougher than with a disc sander, so finish sanding would still be required. American International Industries, 100 New Hampshire St., Cranston, R.I. 02920. Price: $398.

◀ A bit closer

The cordless Model 750 Moto-Tool's design lets fingers get closer to the bit for precise work. It operates at 5,000 and 10,000 rpm and accepts collets and bits up to 1/8 inch. Dremel, 4915 21st St., Racine, Wis. 53406-9989; $30.

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Complete Dent & Ding Kit has filler, hardener, primer, putty and more! 666891 . . . . **9.99**

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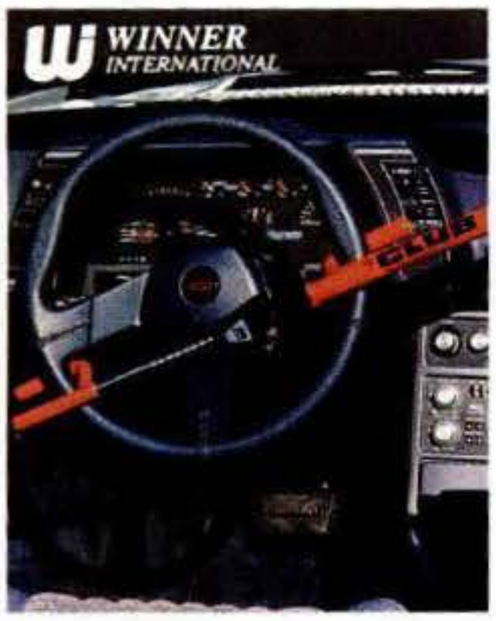
Car Polish. 14-oz. paste needs no buffing to leave a great shine! 512749 . . . **5.99**
16-Fl. Oz. Liquid. . 4.99

Power Plus™ Halogen Headlamps deliver whiter, brighter light ahead to help you see *and* be seen!
Round High or Low-Beam. 217299/283028 . . . . **5.88 Each**
Rectangular High or Low. 210096/292045 . . . . . **6.88 Each**

Concentrated All-Purpose Cleaner & Degreaser. Gallon. 195859 . . . **8.99**

Super Hard Shell® Car Wax. 16-fl. oz. liquid, 9.5-oz. paste. 363291/538827 . . **2.79 Ea.**



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7-In. Diagonal Cutting Pliers are heavy-duty to handle many jobs! 179838 . . . . . **7.99**

9-In. Random Orbital Waxer & Polisher. Hand polishing motion. 516476 **49.99**

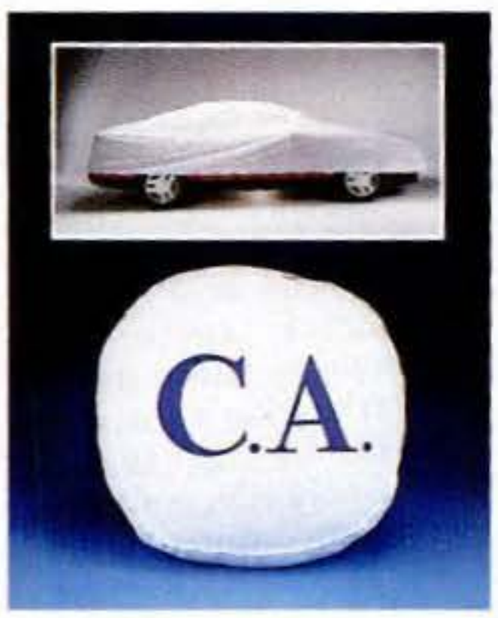
12-Fl. Oz. Brake or 8-Fl. Oz. Power Steering Fluid. Stock up! 146886/443077 . **99¢ Ea.**

Anti-Freeze & Coolant fights corrosion year-round. Stock up! Gal. 471599 . . . . . CHECK OUR LOW PRICE

MASTER
MECHANIC.
Master MECHANIC All-Seasons SAE 10W-30 MOTOR OIL
Master MECHANIC All-Seasons SAE 10W-40 MOTOR OIL
Master MECHANIC DEXRON® II Automatic Transmission Fluid
Master MECHANIC Type FA Automatic Transmission Fluid

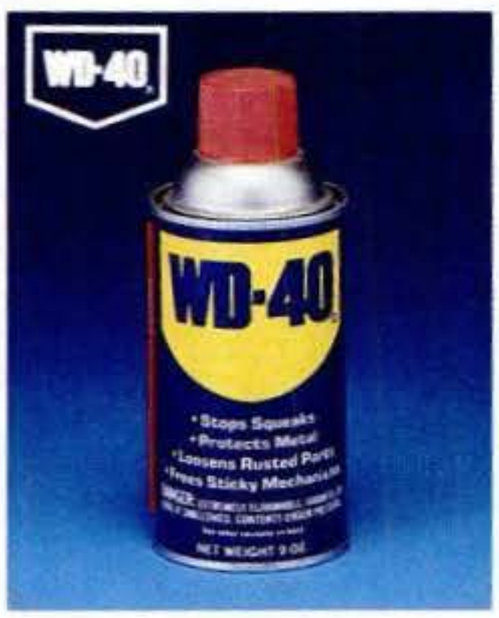
All-Season Motor Oil in your choice of 10W30 or 10W40 formulas. Qt. MM10W30/40 . . . . . **89¢**

Automatic Transmission Fluid. Choose Dexron® II or Type FA formulas. Qt. 587329/386 . . . **99¢**



Nylon Car Cover with tight-fit elastic binding. Fits most cars. 249938 . . . . . **29.99**

22-Fl. Oz. Super Flush removes radiator rust in one easy step! 118844 . . . . . **2.19**



Multi-Purpose Lubricant stops squeaks, loosens rusty parts. 9 oz. 278564 . . . . . **1.39**

Puncture Seal with 8-in. hose inflates tire fast! Easy to use! 12-oz. net wt. 611731 . . . . . **1.79**

Because participating stores vary in size and merchandising policies, some may not stock all items shown and prices may vary. Prices are subject to change without notice and may be higher in Alaska and Hawaii. Prices expire October 14, 1990

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BY MARCELLE M. SOVIERO

What's New RECREATION

Bike on a wall ▲

Is your bike taking up too much room in a narrow hall or garage? This wall-mounted hoist might help. The bike is raised and lowered by a cord running through a geared pulley system; a locking cleat takes the weight between pulls. The floor, not the ceiling, carries the load so there's no risk of crumbling plaster. Ceiling Cycles, 61 Vere Rd., Brighton BN1 4NQ, England.

Clean-air motorboat ▲

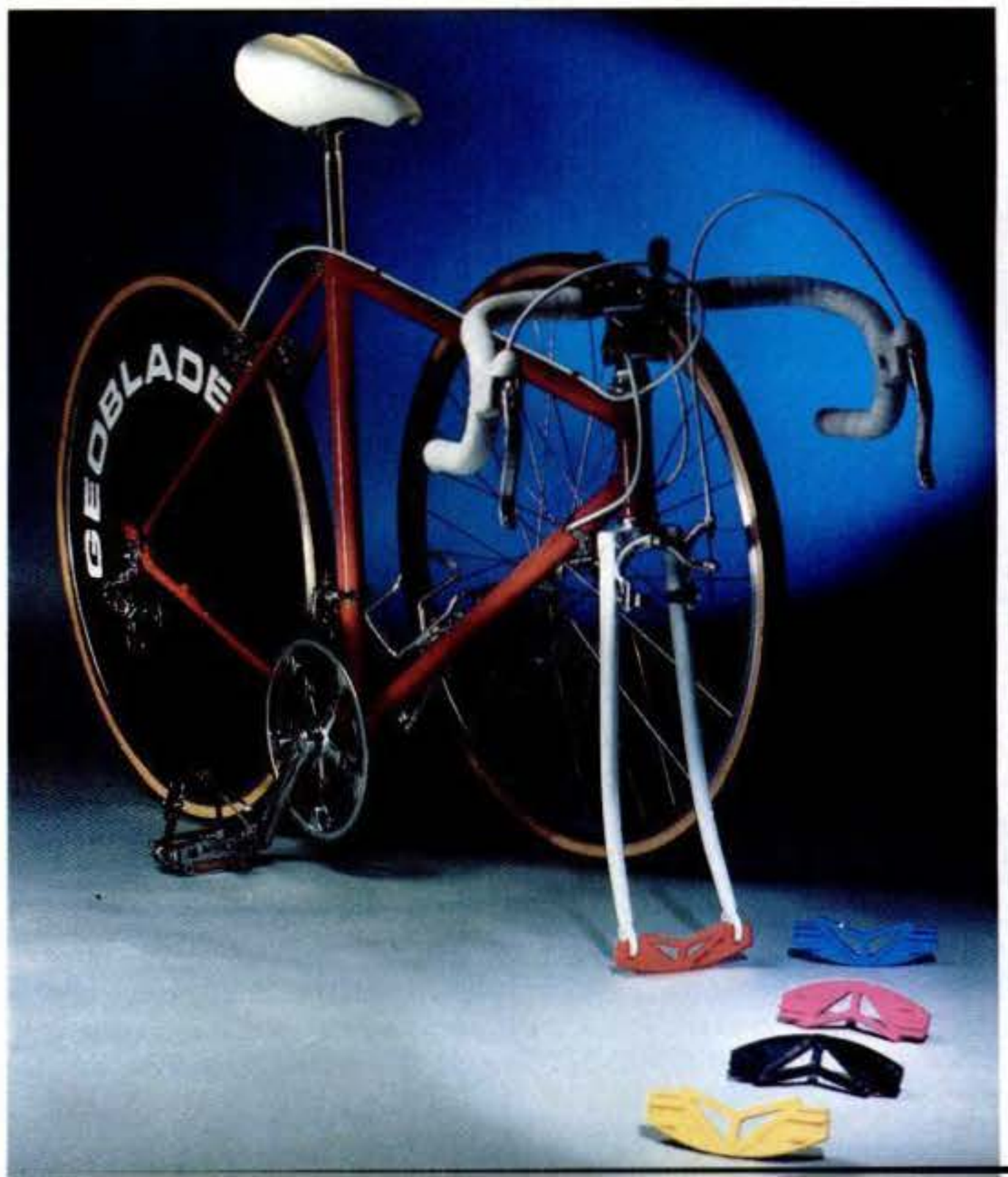
This catamaran, a joint development of Sanyo Electric and Yamaha Motor, is powered by amorphous silicon solar cells. Energy generated by the solar cells flows to the battery, which powers the electric outboard motor. Named *Amorton Flower*, the boat goes 2.5 mph and runs 8.1 miles when the solar battery is fully charged.

Automatic pool cleaner ▶

Tired of cleaning your pool? Let Pool Rover, a programmable robot, do it instead. Choose from four programs covering the floor, walls, steps, and corners, or a mix of the four. A pump draws in up to 70 gallons of water a minute. This suction provides a firm grip while rollers scour the surface. Aqua Products, 25 Rutgers Ave., Cedar Grove, N.J. 07009. Price: $1,650.

Electronic arrow tracker ▲

This electronic tracking system called Beacon will guide you to your arrows up to 300 yards away. A flashlight-size receiver uses a directional antenna to zero in on the signal from a tiny radio transmitter inside the arrow shaft. Electronic Tracking Systems, Box 839, Dundee, Ill. 60118-0839.



◀ Front-fork protector

With the high price tags on bicycles these days, it's wise to avoid damaging them. Geoblade, made of high-impact plastic, fits into your bike's front-fork drop-out slots and prevents possible damage when the front wheel is removed. Geoblade also keeps the bicycle upright during repairs. Lugo U.S.A., Box 30896, Tucson, Ariz. 85751-0896. Price: $5.

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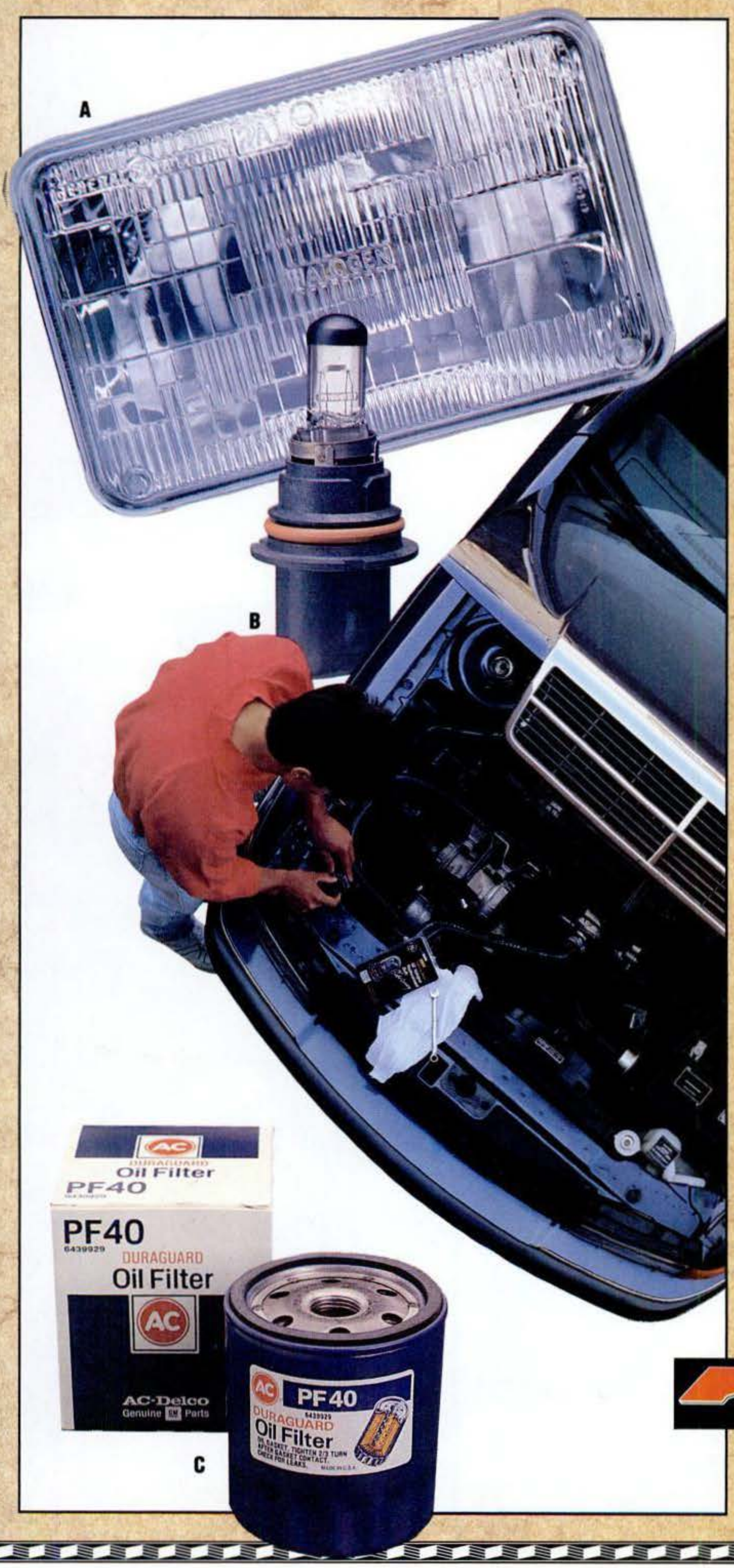

The weeks of September 23 and September 30, 1990

Those who know the road, know the way to Kmart.

When replacing your car's halogen bulbs, Auto Center Manager Bob Christian from the Kmart on N. Michigan Rd. in Indianapolis, IN, recommends that you don't touch the bulb glass. Oil from your hands can cause halogen bulbs to explode.

A **GE Halogen Headlights**. Stock up now and save. Round and rectangular. Four-light system . . . . **Now 5.00** ea.

B **GE Two-Light System or Replacement Bulb**. Dual round or rectangular . . . . . **Now 10.00** ea.

C **AC Duraguard Oil Filter**. Cuts abrasive engine wear. In popular sizes for most U.S. and foreign cars and light trucks. AC quality at a Kmart price . . . . . **Now 1.96**
Limit 3

Kmart the Saving Place

The quality you need, the price you want.

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K mart car audio. Now you can always have front-row seats to a great performance.

Rear speakers deliver more bass, while front speakers accentuate high and mid-ranges better. But whatever the placement, the place to get them is Kmart.

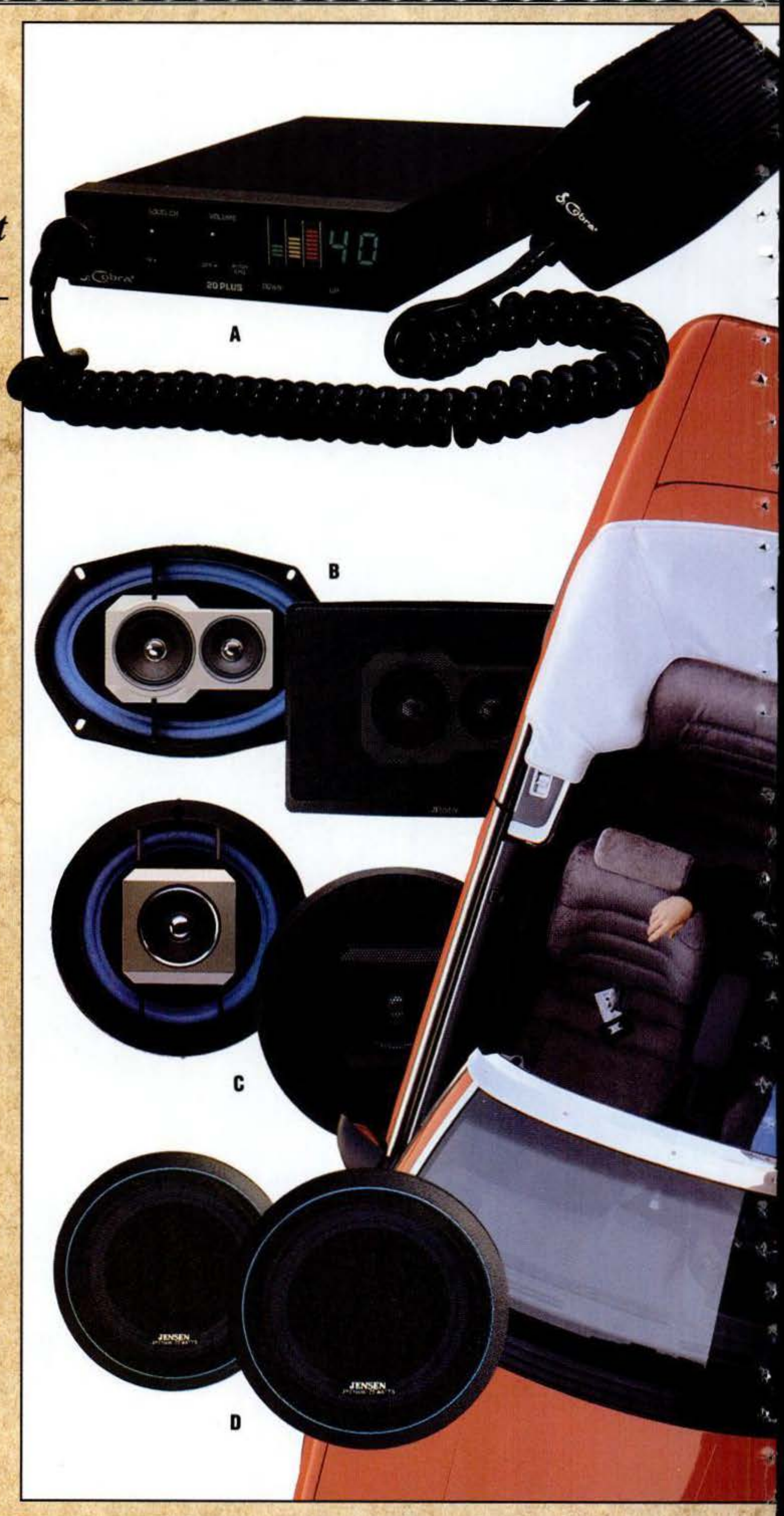
A **Cobra C20 40-Channel CB Radio**. With squelch, digital readout and LED signal strength meter. Instant access to emergency Channel 9 . . **Now 49.00**

B **Jensen JPT1693 6"x 9" Triaxial Speakers**. 75-watt continuous and 140-watt peak-power level. Compact disc ready . . . . . **Now 69.00**

C **Jensen 1652 6½" Coaxial Speakers**. 6½" woofers and 2" dynamic tweeters handle 40-watt continuous and 80-watt peak power. Compact disc ready . . . . . **Now 49.00**

D **Jensen JPT 1606 6" Flush-Mount Speakers**. Fit most 6", 6½", and 5¼" openings. 3/16" mounting depth. 75-watt peak power . . . . . **Now 34.00**

E **Jensen CS2500 AM/FM Stereo Cassette Deck**. Includes automatic program control, seek function and 18-station preset . . . . . **Now 99.00**



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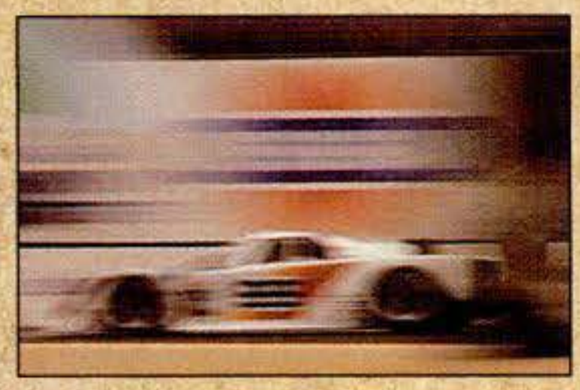

Some of the world's fastest cars have broken the sound barrier. And now Kmart makes it easy for your car to break the sound barrier by offering great car audio at prices you can afford.

F Audiovox AMP760CS 40-Watt Graphic Equalizer/Amplifier. With front and rear fader controls, and dual LED power meters . . . . **Now 24.00**

G Jensen CS4500 AM/FM Stereo Cassette Deck. Auto-reverse capability with seek, fader and automatic program control . . . . . **Now 119.00**

H Sparkomatic SR300 AM/FM Car Stereo Cassette Player. Compact unit with fast forward, eject switch and stereo indicator . . . . . **Now 29.97**

I Pioneer KP220A In-Dash AM/FM Cassette Stereo. Auto replay, fast forward and rewind. Balance controls . . . . . **Now 119.00**

J Pioneer KE2022 DLX ETR AM/FM Stereo Cassette. Electronically tuned, 15-station preset and auto reverse.
Includes locking fast forward and rewind . . . . . **Now 159.00**

K Whistler WH225 Radar Detector. Low-level signal monitoring with sensitivity to pulse signals. X and K band monitoring and three-segment LED array . . . . . **Now 59.00**
Not available in CT and VA.

L Whistler WH750 Deluxe Radar Detector. Full-feature design including highway/city mode, five-segment LED array and advanced selectivity system . . . **Now 149.00**
Not available in CT and VA.

Kmart the Saving Place

The quality you need, the price you want.

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When your car needs some R & R, come to K mart.

Angie Yang of Silver Springs, MD, knows what it takes to change a flat tire. 1. A flat tire. 2. A socket set from the Kmart on Connecticut Avenue.

A **Two-Ton Hydraulic Bottle Jack.**
Designed for multiple uses . **Now 8.97**
Four-Ton Jack . . . . . **Now 11.97**
Six-Ton Jack . . . . . **Now 13.47**

B **Two-Ton Hydraulic Floor Jack.**
Swivel caster for easy positioning. Rectangular saddle. Wheels for mobility. Model No. 41-14 . . . . . **Now 26.97**

C **Three-Ton Jack Stands.**
Two ratchet-adjustable jack stands with locking pins . . . . . **Now 17.97**

D **Six-Gallon Portable Air Tank.**
Features solid brass manifold, pressure gauge, and industrial hose. On/off switch . . . . . **Now 24.97**

E **Campbell Hausefield Two-Horsepower Air Compressor.** 125 psi. Includes blowgun and couplers. UL listed . . **Everyday low price 298.98**

F **Three-in-One Air Compressor.**
Compact 12-volt compressor inflates tires, balls, and mattresses. Includes gauge . . . . . **Now 17.00**

Style and manufacturer may vary.

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Bench Top tools — "the last set of tools you will buy." Limited warranty, details in store.

G 224-Piece Tool Set with Chest. Complete set of 1/4", 3/8" and 1/2" standard and metric sockets along with screwdrivers and combination wrenches. Roll-around chest and cabinet . . . . . **Now 199.00**

H 41-Piece 1/4" & 3/8" Drive Socket Set. With fractional and metric sockets. Handy around the home, shop or car. Save 25% . . . . . **Now 7.47**

I Bench Top 106-Piece Tool Set with Case. Includes 1/4", 3/8" and 1/2" drive sockets and combination wrenches. Meets or exceeds all federal specifications . . . . . **Now 67.47**

J 22-Piece Socket Set. With metal case. Ideal for home, car, or business. In fractional and metric sizes. Save 25% . . . . . **Now 5.97**

K Stack-On Six-Drawer Chest. Six large flush-front drawers. Comes in two conventional sizes for total storage versatility . . . . . **Now 81.00**

Stack-On Three-Drawer Cabinet. 26¾" x 18" x 29" professionally crafted cabinet. Includes security lock and key . . . . . **Now 99.00**

Stack-On Three-Drawer Add-On Cabinet. Finish front-style drawers with large storage capacity . . . **Now 45.00**

Stack-On Hang-On Cabinet. Attaches to side to create additional work space. Quality construction . . . **Now 69.00**

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Quality that performs best under pressure. K mart.

Driving worn-tread tires on wet surfaces can cause hydroplaning. A condition when water lifts your car off the road and reduces steering control. If your tires are worn, you'll find quality replacement tires at the Kmart Auto Center.

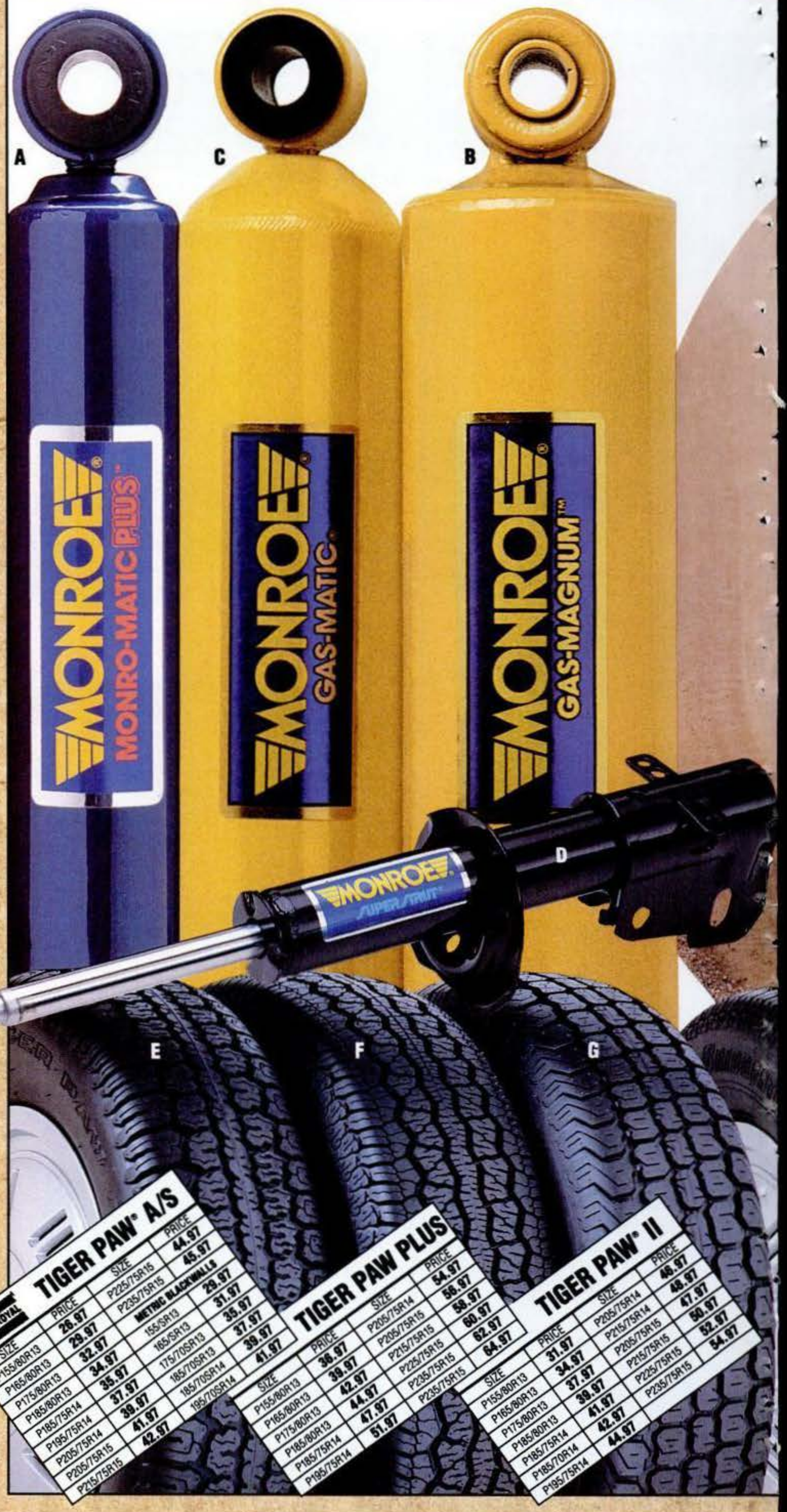
A **Monroe-Matic Plus Shocks.** Gas-charged shock absorbers for many U.S. and import cars. Warranted performance. Installation available in stores with service.
Carryout . . . . . **Now 12.97** ea.

B **Monroe Gas Magnums.** The shock for light-duty trucks in various sizes.
Nitrogen charging and priming valve. Warranted performance.
Carryout . . . . . **Now 21.97** ea.

C **Monroe Gas-Matic Shocks.** The ultimate riding comfort and control for many U.S. and import cars. Installation available in stores with service.
Carryout . . . . . **Now 16.97** ea.

D **Monroe Super Struts.** Fronts only. All strut prices are carryout. Installation available in stores with service. Parts and service are extra.
Omni, Horizon . . . . . **24.97** ea.
GM, X and A Body* . . **29.97** ea.
Mustang, T-Bird . . . . **34.97** ea.

*Thru 1986, gas struts $20.00 more per pair.



UNIROYAL TIGER PAW® A/S

SIZE	PRICE
P155/80R13	26.97
P165/80R13	29.97
P175/80R13	32.97
P185/80R13	34.97
P185/75R14	35.97
P195/75R14	37.97
P205/75R15	39.97
P215/75R15	41.97
P225/75R15	42.97
P235/75R15	44.97
METRIC BLACKWALLS	
155/SR13	29.97
165/SR13	31.97
175/70SR13	35.97
185/70SR13	37.97
185/70SR14	39.97
195/70SR14	41.97

TIGER PAW PLUS

SIZE	PRICE
P155/80R13	36.97
P165/80R13	39.97
P175/80R13	42.97
P185/80R13	44.97
P185/75R14	47.97
P195/75R14	51.97
P205/75R14	54.97
P205/75R15	56.97
P215/75R15	58.97
P225/75R15	60.97
P235/75R15	62.97
	64.97

TIGER PAW® II

SIZE	PRICE
P155/80R13	31.97
P165/80R13	34.97
P175/80R13	37.97
P185/80R13	39.97
P185/75R14	41.97
P185/70R14	42.97
P195/75R14	44.97
P205/75R14	45.97
P215/75R14	46.97
P205/75R15	47.97
P215/75R15	50.97
P225/75R15	52.97
P235/75R15	54.97

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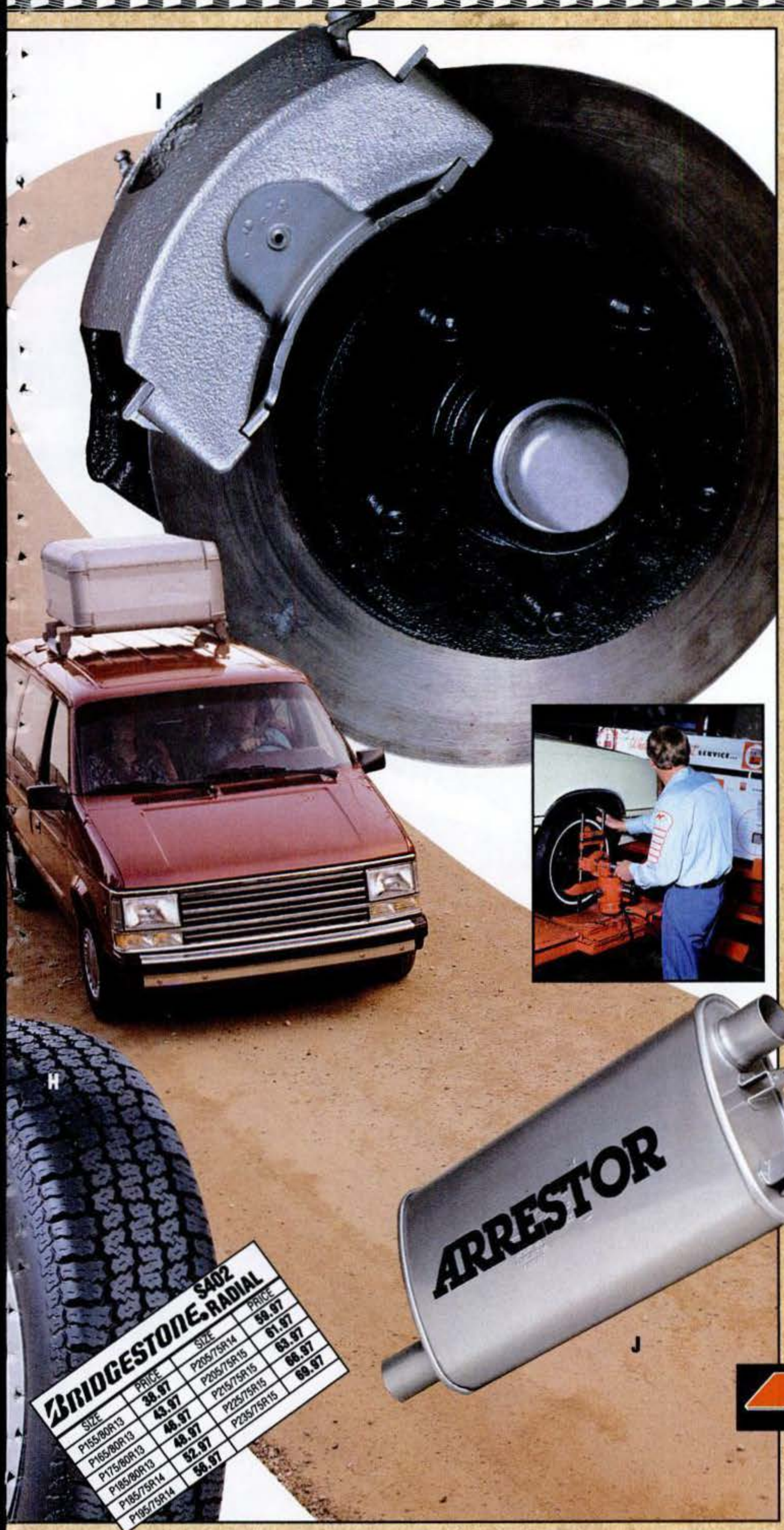

Name-brand Uniroyal, Tiger Paw and Bridgestone radials at everyday low prices.

E **Tiger Paw All-Season Radial Tires**. 35,000-mile warranty.
P155/80R13 whitewall . **Now 26.97***

F **Tiger Paw Plus Tires**. 55,000-mile limited warranty. All-season tread and radial-ply construction for solid road grip.
P155/80R13 whitewall . **Now 36.97***

G **Tiger Paw II Tires**. 45,000-mile warranted steel-belted radials with a wide footprint for long mileage.
P155/8013 whitewall . . . **Now 31.97***

H **Bridgestone S402 Tires**. Speed rated to 112 mph. Steel-belted responsive handling. 55,000-mile warranty.
P155/80R13 whitewall . **Now 38.97***

I **Two-Wheel Disc/Drum.**
For many U.S. cars, imports and light trucks. Limited 30,000-mile warranty available. See details in store. Semimetallic pads extra. Additional parts and services, which may be needed, at extra cost . . . **Now 59.97**

J **Arrestor Plus Muffler**. "The last muffler you will buy." Provides long-lasting service for most cars and light trucks. Muffler prices are carryout in stores with service. Installation, clamps, and hangers are extra . . . . **Now 17.97**

Arrestor Muffler* . . . . . **Now 13.97**

*Limited 1-year warranty.
All tires $1.00 more in Florida, Oklahoma and Washington.

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K mart's starting lineup.

Here's your chance to pick up a new set of wheels during the Kmart/Texaco/Havoline radio-controlled car giveaway. One car will be given away in each store. There's no purchase necessary, so come in to Kmart and find out how you can win.

A **Schumacher 6- and 12-Volt 200-Amp Power Booster**. Deluxe roll-around charger delivers 200 amps of starting power. Automatic shutoff . . . . . **Now 79.97**

Save every day on Exide batteries at K mart.

B **Exide Centura 850 75-Month Battery**. Our most powerful battery. 850 cold-cranking amps and 115-minute reserve capacity for many cars and trucks . . . . . **Now 59.77***

C **Exide Centura 650 75-Month Battery**. 650 cold-cranking amps of starting power. For many cars and trucks . . . . . **Now 49.77***

D **Exide Motivator Battery 65**. Up to 550 cranking amps of starting power and reserve capacity for many cars and trucks. 65-month warranty . . . . . **Now 39.77***

Motivator 45 Battery . Now 29.97*

*All batteries "with exchange." $1.50 more in Florida.

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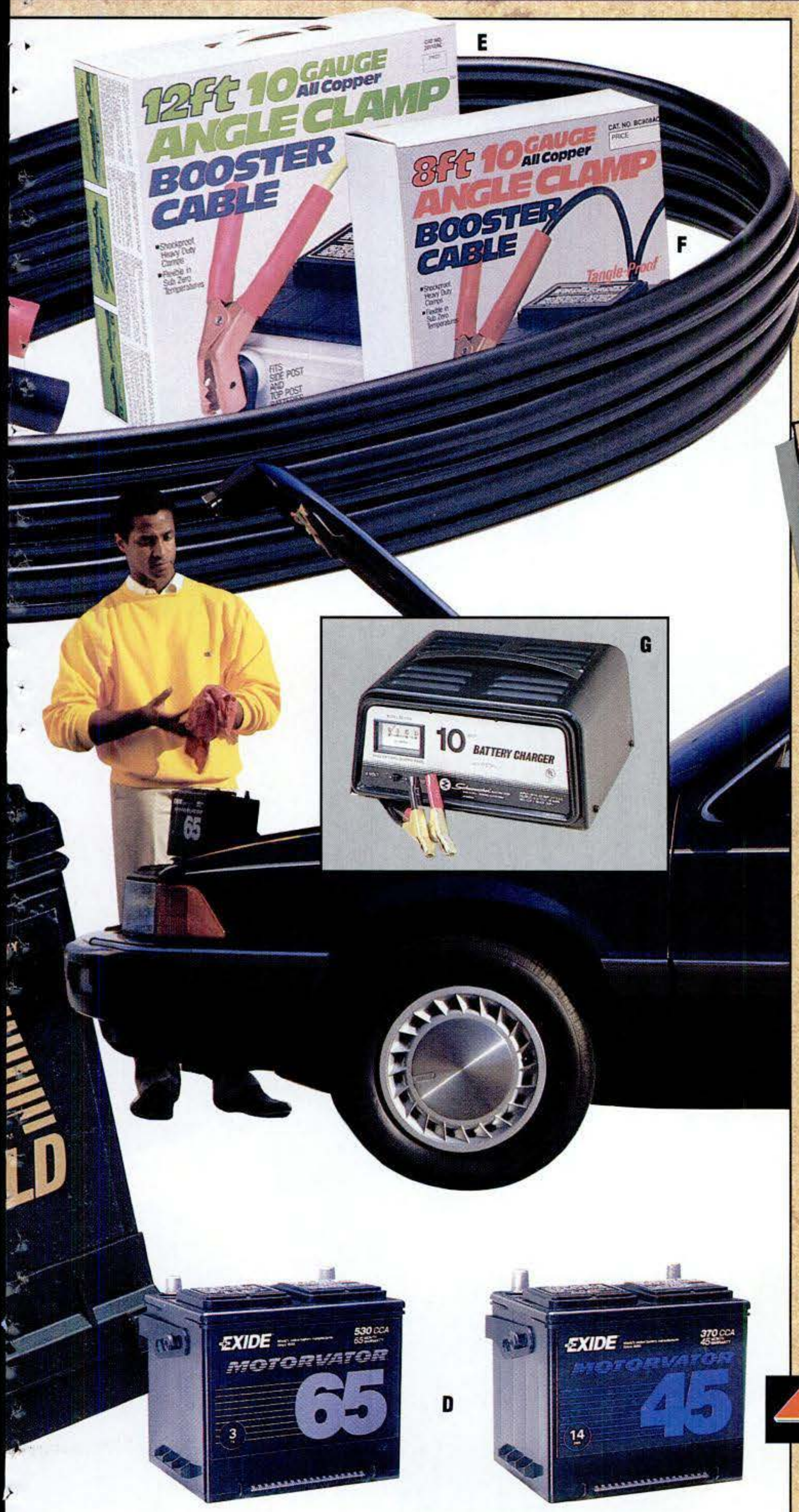

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ANTI-CORROSION RECIPE

INGREDIENTS:
1 cola drink or 2 or 3 ounces of baking soda

DIRECTIONS:
Pour cola or water and baking soda solution over car battery terminals. Use toothbrush to scrub corrosive hard spots.

E Carol Cable Twelve-Foot Booster Cable. Tough 10-gauge copper tangle-free cable for side or top terminals . . . . . **Now 8.97**

F Carol Cable Eight-Foot Booster Cable. Heavy-duty 10-gauge tangle-proof booster cable for side or top terminals . . . . . **Now 5.97**

G Schumacher 10-Amp Battery Charger. Compact high-rate charger charges 6- and 12-volt car batteries in three to five hours . . . . . **Now 29.97**

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K mart. Your most important truck accessory.

Driver Michael Andretti isn't lonely at the top because his dad, Mario Andretti, keeps him company. In Portland, OR, the Andrettis won 1st and 2nd place, respectively, in cars sponsored by Kmart.

A Ultima Four-Piece "Tacky Back" Mat Set. Plush 35-oz. carpet with washable non-slip tacky back to keep mat in place. Available in blue, brown, burgundy, and charcoal . . **Now 18.97**

B Two-Piece Truck Mat Set. "Tacky back" protects your natural truck carpeting. Choice of colors . **Now 9.97**

C Four-Piece Supreme Mat Set. Heavy-duty rubber mats. Your choice of blue, burgundy, brown, or charcoal color . . . . . **Now 12.97**

D Three-Piece Mini Van Mats. Carpeted set with "tacky back" adhesive. Mat styles available for Ford, Chevy, and Chrysler. Assorted colors . **Now 14.97**

E Grand Sport Truck Seat Covers. Plaid bench seat covers for standard and mini trucks . . . . . **Now 22.97**
Western Style . . . . . **Now 19.97**

F Sagaz Royal Mouton Sheepskin Seat Covers. Luxurious comfort in electrified deep-pile 100% natural wool front. Bucket seat styles in silver, wine, and champagne colors . **Now 39.98** ea.

G Saddleman Grand Sport Seat Covers. Sporty loop-pile velour. Tazlanized olefin provides comfort and protection. Selection of colors. Fit most bucket seats . . . . . **Now 19.88**

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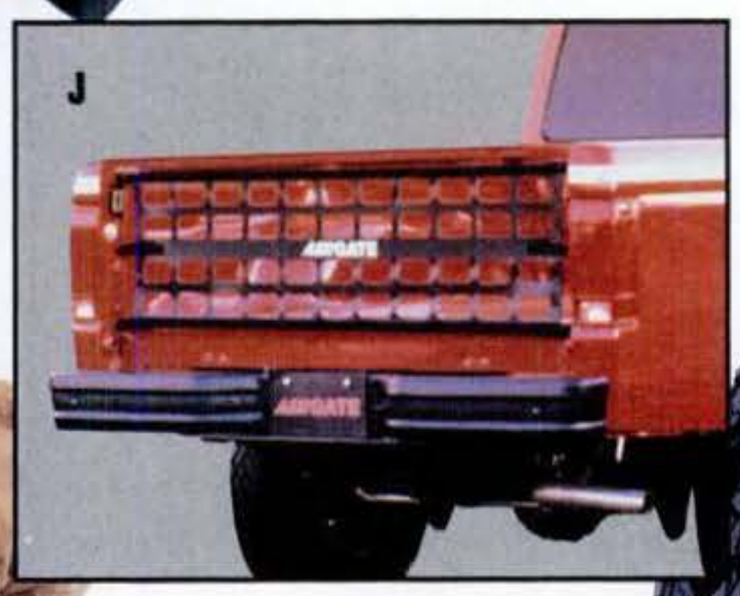

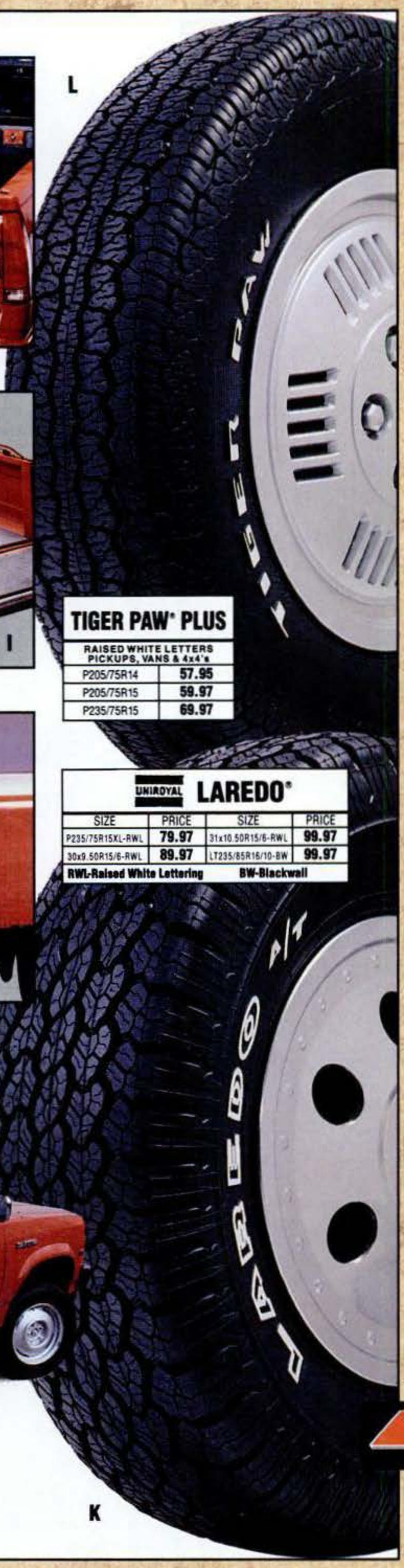

TIGER PAW® PLUS	
RAISED WHITE LETTERS PICKUPS, VANS & 4x4's	
P205/75R14	57.95
P205/75R15	59.97
P235/75R15	69.97

UNIROYAL LAREDO®			
SIZE	PRICE	SIZE	PRICE
P235/75R15XL-RWL	79.97	31x10.50R15/6-RWL	99.97
30x9.50R15/6-RWL	89.97	LT235/85R16/10-BW	99.97
RWL-Raised White Lettering		BW-Blackwall	

H **Contico Truck Toolbox**. Sits directly on floor of full-size and mini trucks for increased storage capacity. Constructed of maintenance-free polyethylene . . . . . **Now 69.97**

I **Truck Bed Mat**. Heavy-duty custom-fit bed mat fits most trucks and protects truck bed . . . . . **Now 39.88**

Tailgate Mat Protector . . **Now 14.88**

J **Airgate Truck Tailgate Net**. Fits mini or full-size trucks. Increases fuel economy. Easy installation . . . . . **Now 17.97**

K **Uniroyal Laredo All-Season Light Truck Tires**. Original equipment replacement for pickups, vans, and 4x4s. Wide treads and multi-ply design for extra strength. 40,000-mile warranty. P235/75R15XL-RWL . . **Now 79.97***

Win a Chevrolet Blazer or other exciting prizes in the K mart/Uniroyal Tire Sweepstakes. See your participating K mart or Uniroyal dealer for details and enter today!

L **Tiger Paw Plus RWL Tires**. Original equipment replacement for pickups, vans, and 4x4s. Provides year-round performance. Raised white letters. 55,000-mile warranty. P205/75R14 . . . . . **Now 57.97***

M **Tarp**. Rip-proof polyethylene. Waterproof. Popular multi-use sizes for cars, boats, and trailers. Save 50% . . . . . **Now 3.98-13.48**

*Tires in stores with service only. $1.00 more in FL, OK and WA.

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Tips for a clean driving record.

A Armor All Protectant.
Economy 32-oz. refill protectant with 8-oz. wax and 4-oz. car wash sampler. . . . . **Now 5.97**

B Armor All Bonus-Size Protectant.
Beautifies and protects rubber, vinyl, and leather. 20 fl. oz. . . . . **Now 3.88**

C Anco Wiper Blade or Refills. Popular sizes for most cars and light trucks. One wiper blade or two refills per pack. Your choice . . . . . **Now 2.96** pk.

D Turbo TEK Turbowash Pulsator.™
With pulsating action for better cleaning. Ideal use for cars, vans, and RVs. Includes 16-oz. Soft Suds. Rebate limited to manufacturer's stipulations. Details in store. . . . . K mart Sale Price **15.97**
Less Mfr.'s Rebate 5.00
Price After Rebate **10.97**

E Simple Green All-Purpose Cleaner.
Cleans home and auto surfaces such as wheels, tires, vinyl tops, and plastics.
24 oz. . . . . **Now 3.88**
67-Fl.-Oz. Economy Size . . . Now 5.97

F Amoco Multipurpose ATF. Dexron II/Mercon automatic transmission fluid for most cars and light trucks. One qt. fl. oz. Limit 12 . . . . . **Now 96¢** qt.

On sale September 23 through October 6, 1990, at most K mart stores across the U.S.A.

K mart ADVERTISED MERCHANDISE POLICY
Our firm intention is to have every advertised item in stock on our shelves. If an advertised price is not available for purchase due to any unforeseen reason, K mart will issue a Rain Check on request for the merchandise (one item or reasonable family quantity) to be purchased at the sale price whenever available or will sell you a comparable quality item at a comparable reduction in price.

DISCOVER VISA MasterCard

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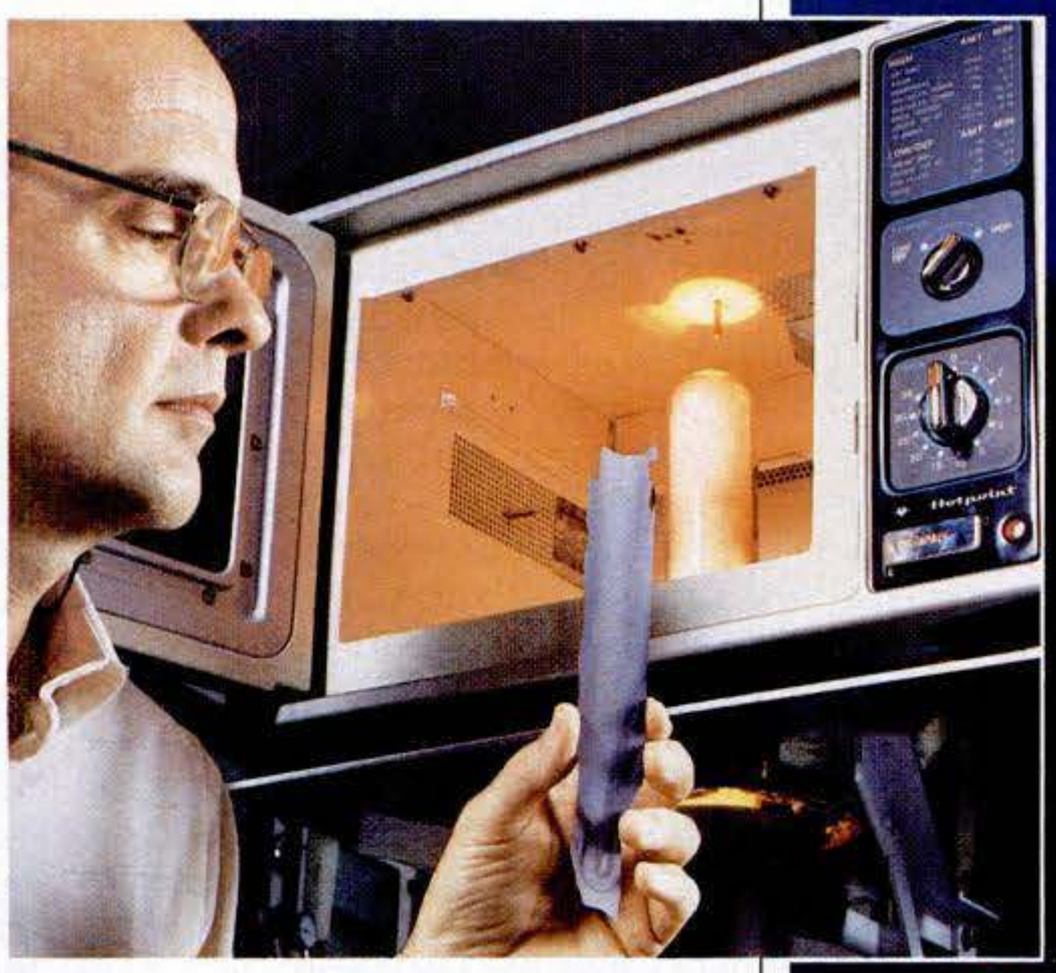
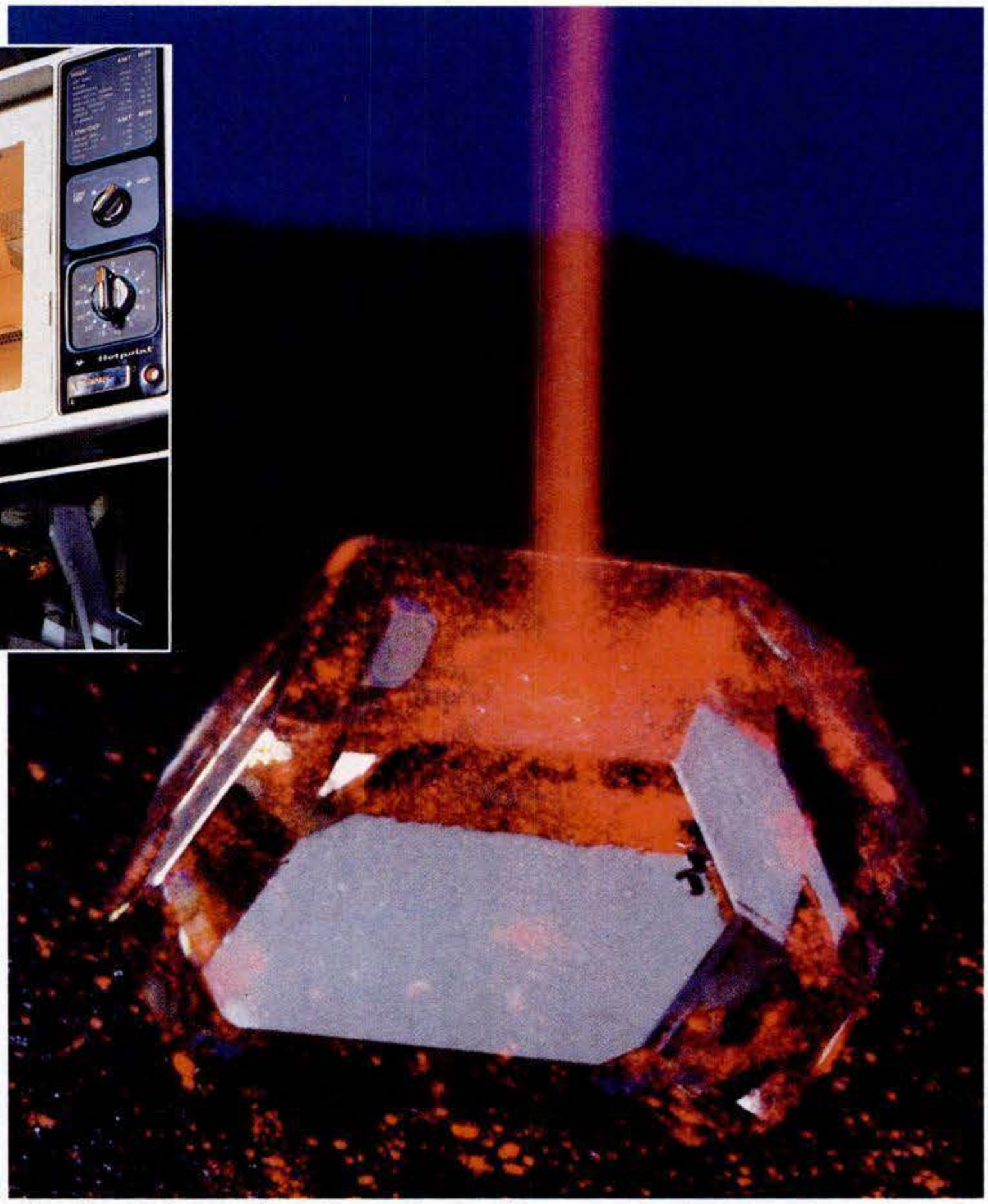
Science Newsfront

By ARTHUR FISHER





A laser beam probes a GE diamond. Inset: Thomas Anthony inspects a polycrystalline diamond sheet.

A gem of an idea

General Electric scientists have synthesized a new form of gem-quality diamond, shown at right, that has unique properties not shared by natural diamonds.

At room temperature, the gems are the most efficient conductors of heat known—50 percent better than natural diamond, the previous champion, and 850 percent better than ordinary copper wire. Moreover, the crystals can resist damage from powerful lasers 10 times better than natural diamond, thus allowing the passage of 10 times more light before breaking down.

These properties will prove a boon, GE's Walter L. Robb predicts, to three of the nation's most important technologies: electronics, lasers, and communications.

Key to the properties of the new diamond, says Robb, is that normally mined diamonds consist of two isotopes of carbon, carbon-12 and carbon-13. The carbon-13 is an impurity that retards heat conduction, even though it is present only in small concentrations in natural crystals.

"The secret to the unparalleled heat-transfer performance of these crystals," says Robb, "is that they contain almost none of the carbon-13 isotope that subtracts from natural diamond's heat-transfer properties."

The difference is an order of magnitude, nicely corresponding to the order-of-magnitude improvement in performance: The best natural-diamond heat conductors consist of 99 percent carbon-12, whereas the new GE diamonds have more than a 99.9 percent concentration of carbon-12.

All the same, this level of performance came as a welcome surprise to the GE researchers. The best available theory of thermal conductivity in solids had predicted only a fractional improvement in heat transmission.

"It's as if you went into a high-jump competition hoping to beat the world record slightly by going a few inches over eight feet and came away with a high jump of twelve feet," says Robb.

The proprietary process GE uses to synthesize the gems, which are up to one carat in weight, combines two previously known techniques. The older and more familiar way to make diamonds relies on subjecting carbon to enormous pressure—close to a million psi—and temperatures above 2,500 degrees F. The newer technique is a chemical process in which diamond crystals are formed by vapor deposition.

The two-stage method for producing isotopically pure diamonds was invented by physicist Thomas R. Anthony, materials scientist William F. Banholzer, and technical specialist James F. Fleischer, all of GE.

Anthony is shown in the inset photo holding a sheet of polycrystalline diamond that has been enriched with carbon-12 by the vapor deposition method. The enriched diamond sheets next are ground to a powder. The dia-

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mond powder is then subjected to high heat and pressure to be converted into gem-quality stones.

The unique diamonds will be manufactured and marketed by GE Superabrasives of Worthington, Ohio. Cut into thin slices, the material will serve as heat sinks for telecommunications systems, computers, and integrated circuit chips. It should enhance designers' ability to cram ever more devices onto chips and ever more chips into tight spaces where efficient heat dissipation is vital. And it could prove ideal in the fabrication of mirrors and windows of high-power lasers.

Space coolers

The first of many miniature cryogenic coolers, or refrigerators, that will fly on space missions during the 1990s is being tested at the Earth Observation and Science Division of British Aerospace in Bristol, England.

Why refrigerators in space? Many sensors and other precision scientific instruments operate best at cryogenic, or very low, temperatures because at those levels thermal noise is suppressed, ensuring that faint signals are undistorted.

These Stirling-cycle mechanical coolers were developed in technology programs at Oxford University and the Rutherford and Appleton Laboratory in England. They have an operational range between 120 degrees and 60 degrees Kelvin (minus 153 degrees C down to minus 213 degrees C). Some have already been sent to NASA's Jet Propulsion Laboratory and the U.S. Naval Research Laboratory. They will help support the ambitious U.S. Earth Observation Systems as well as a number of future European space missions, including the Polar Orbiting Platform due to fly late in the 1990s.

Putting atoms in their place

The emergence of a new generation of ceramic engine parts, characterized by high strength, light weight, and increased heat resistance, promises to make internal combustion engines much lighter and more powerful than had been previously thought possible. One obstacle, however, has been the difficulty in making smooth, easily lubricated surfaces for such parts. Unlubricated ceramic surfaces in contact with other surfaces simply encounter too much sliding friction. And many lubricating materials will not adhere to ceramics by conventional means.

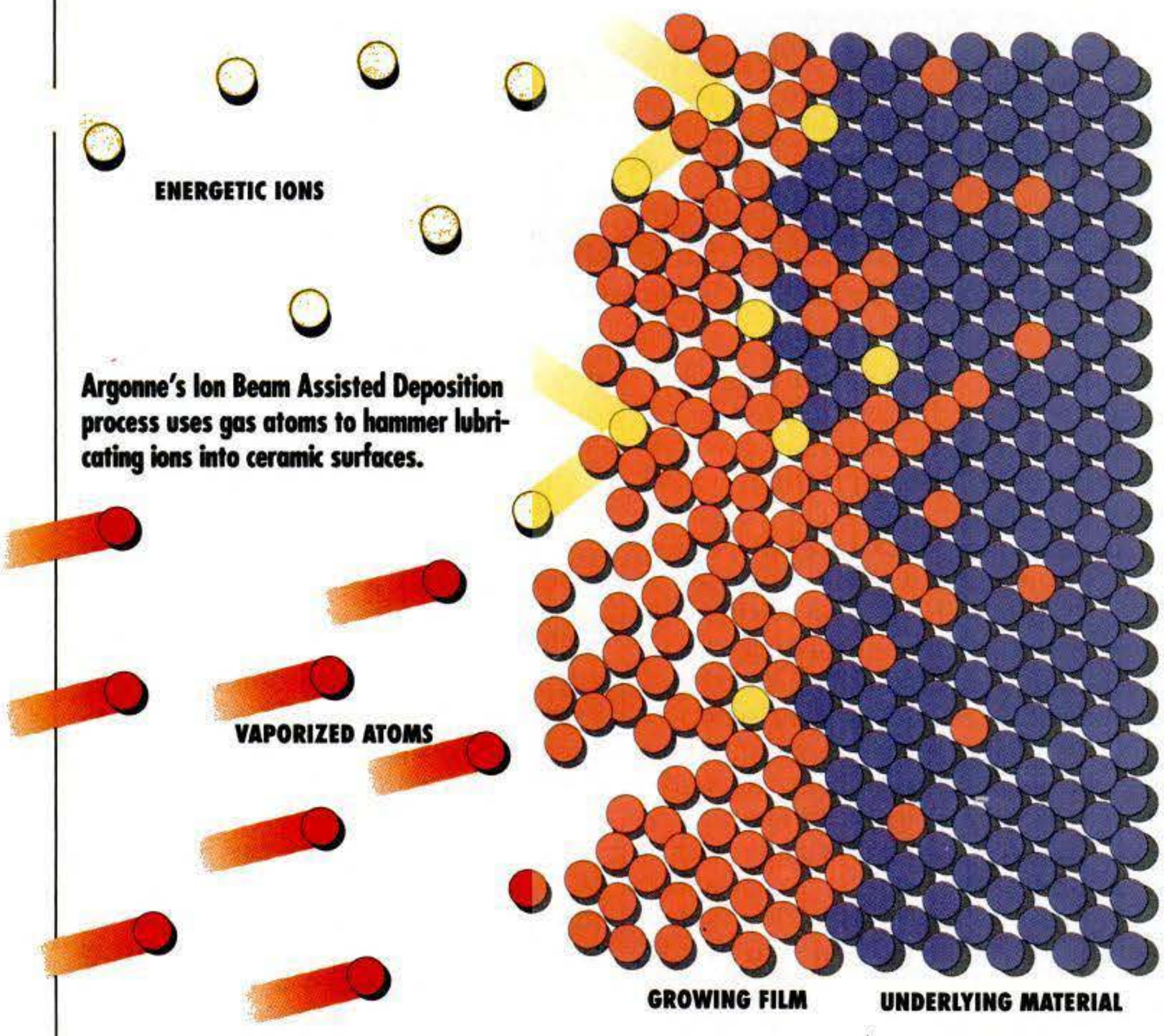
Now researchers at Argonne National Laboratory in Argonne, Ill., are trying out a technique that uses ion beams to "nail" thin, slippery coatings to ceramic materials. The technique, called Ion Beam Assisted Deposition (IBAD), uses ions of noble gases as "tack hammers" to nail individual atoms of the desired coating material deep into the ceramic surface.

The new process combines aspects of two earlier techniques, vapor deposition and ion implantation, each of which had drawbacks.

In vapor deposition, the coating material is heated till it vaporizes and is then allowed to condense onto the surface to be coated. But the method commonly led to poor adhesion.

Ion implantation involves bombarding a base material with ions (atoms that are electrically charged) of the coating material so that some of them remain embedded in the surface. The process requires extremely high voltage levels, and it is hard to obtain surface layers more than a few hundred molecules thick.

In the IBAD process, shown below, both the vapor deposition and the ion implantation techniques take place simultaneously inside the same chamber. One or two heating hearths provide precise temperature control in generating a vapor that will be deposited as a thin film. (With two hearths, two different materials can be vaporized and deposited together, giving the researcher the ability to control the coating's exact composition.) The ions that do the hammering are made by stripping electrons from atoms of argon and neon, sometimes combined with nitrogen. These ions are accelerated toward the target surface at energies ranging from 50 volts to a few thousand. That compares with a level of several million volts needed for direct ion implantation.



Argonne's Ion Beam Assisted Deposition process uses gas atoms to hammer lubricating ions into ceramic surfaces.

The case of Vincent's ear

Vincent van Gogh cut off part of his left ear and bestowed it on a prostitute because he was Looney Tunes, right?

Maybe not. Dr. I. Kaufman Arenberg of the Colorado Neurologic Institute and his colleagues believe that the diagnosis of epilepsy and insanity made by van Gogh's physicians was in error. What really made the tortured artist's life a misery and led to his suicide at the age of 37, they conclude, was a severe case of Meniere's disease, a disorder of the inner ear that is fairly common but was often misdiagnosed as epilepsy well into the 20th century. And he most probably mutilated himself in a vain attempt to get rid of the tinnitus—a sometimes maddening buzzing or ringing in the ear—that is a recurrent symptom of the disease, along with severe vertigo and

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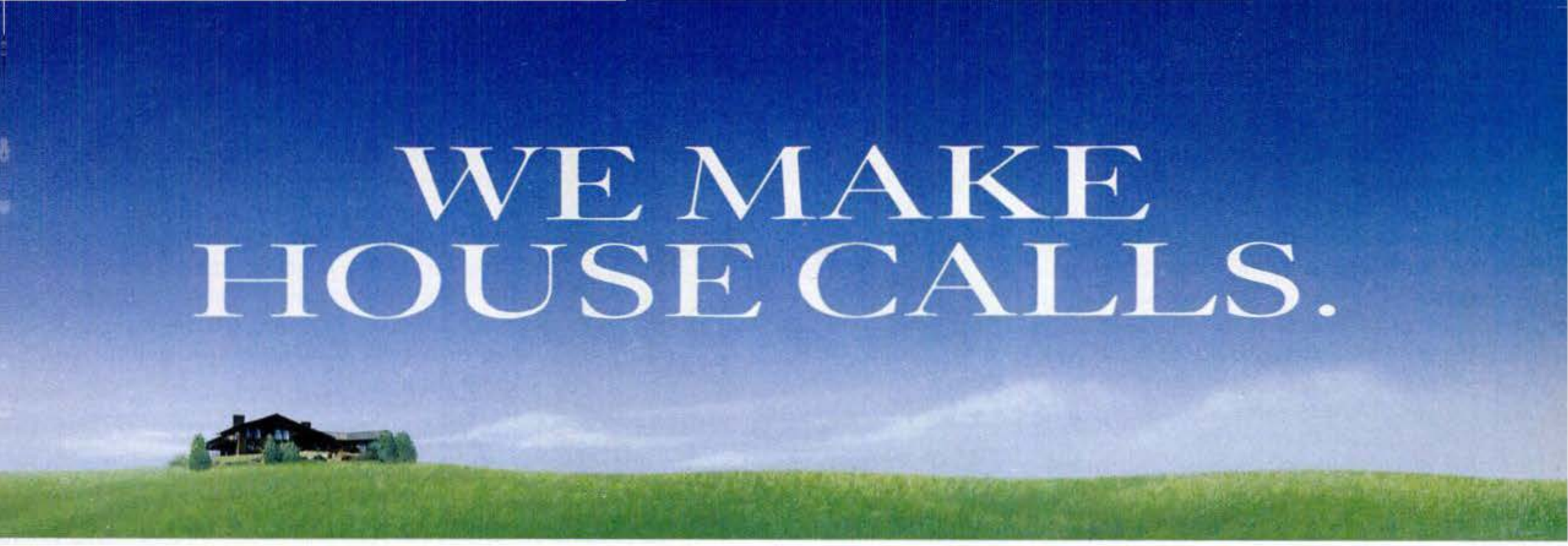

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nausea, visual disturbances, and often deafness.

In the *Journal of the American Medical Association*, Arenberg and his colleagues write that van Gogh's letters "reveal a man constantly in control of his reason, and suffering from severe repeated attacks of disabling vertigo, not a seizure disorder ...His voluntary admission to the asylum at St.-Rémy hoping to find help for his attacks of vertigo...and his rational behavior at the asylum...should forever banish the notion that he was an epileptic or 'mad.' "

Reading writing

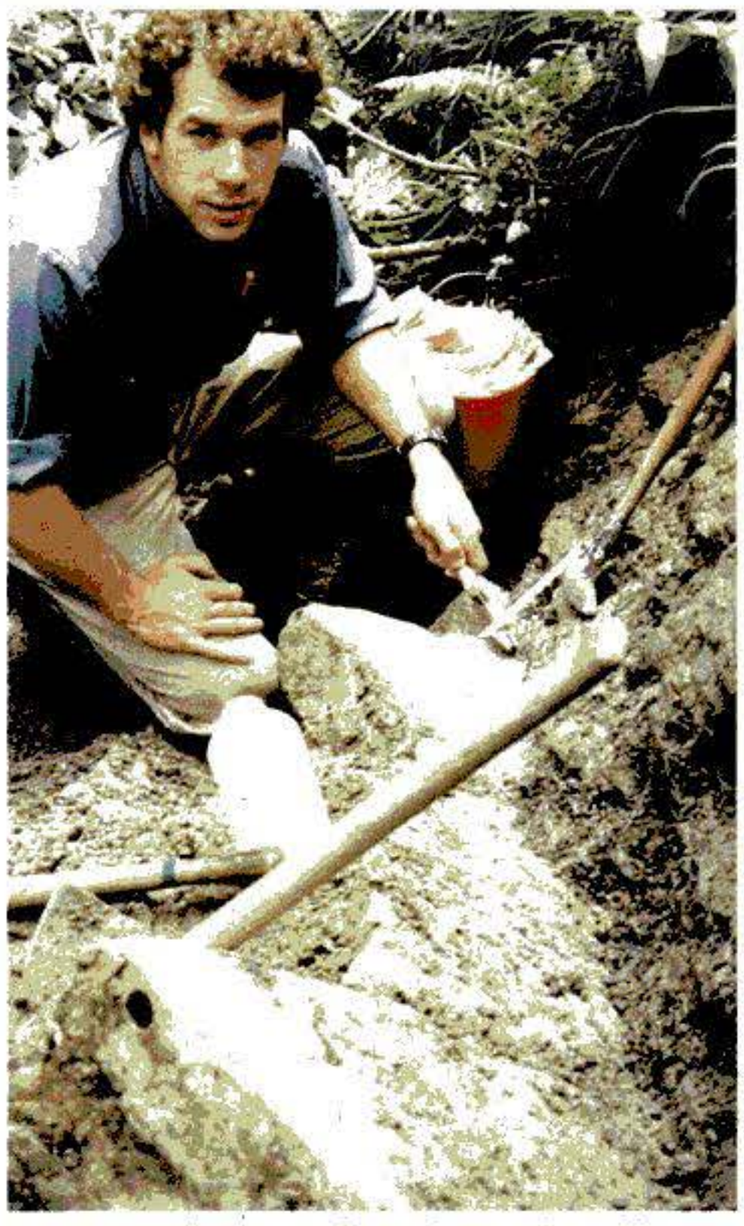
Researchers at the IBM T. J. Watson Research Center have reported the first accurate, real-time computer recognition of run-on hand-printed characters. In this kind of handwriting, the letters can run together, touch, and even overlap. The previous state of the art was limited to recognition of hand-printed characters that were spatially separated or confined to boxed areas. Recognition of cursive script, however, remains a distant goal, largely because individuals vary so widely in their writing styles. Samples of all four types of handwriting appear below.

At about the same time as the IBM report, the U. S. Commerce Department's National Institute of Standards and Technology (NIST) announced it had compiled a first-of-its-kind data base containing more than a million hand-printed characters. The aim is to help measure the performance of systems designed to recognize hand-printed numbers and letters.

Where did the big one hit?

Scientists are still debating whether a large body's collision with Earth 65 million years ago, at the end of the Cretaceous period, was principally responsible for the mass extinctions of life forms that occurred then. But over the 10 years since the giant impact theory was first enunciated, much of the scientific community has come to agree that a large asteroid or comet did indeed crash violently into our planet. The view is supported by a great deal of physical evidence, including the presence of a worldwide layer of material rich in iridium, an element rare in Earth's crust but abundant in extraterrestrial bodies such as meteors.

But what might be the most impressive evidence of all—finding the actual site of the impact—has been missing. There are many impact craters pockmarking Earth's surface, but none correspond in age or size to the big one sought. Conclusion: The extraterrestrial body must have landed somewhere in the oceans.



University of Arizona planetologist Alan Hildebrand seeks evidence of a giant meteor impact.

Now two planetary scientists at the University of Arizona in Tucson, Alan R. Hildebrand (shown in the photo) and William V. Boynton, believe they have located a possible candidate for the 65-million-year-old crater site. It lies buried under more than a mile of sediment in the Colombian Basin of the Caribbean Sea, and at 180 miles in diameter is twice the size of any impact crater on land.

They formed this conjecture on the basis of widespread geological evidence, including the finding of "impact-wave deposits," great heaps of coarse rock that have been deposited in Mexico, the Caribbean islands, and along the U.S. coast from Texas to New Jersey. The rock piles are the signature of the great three-mile-high wall of water that would have radiated outward from the impact site, carving the sea floor and eroding and redepositing sedimentary rock.

One of the largest such deposits Hildebrand and Boynton have discovered so far, in Cuba, measures 300 miles in length and up to 500 yards thick. It contains fragments of transported, fractured rock up to five feet in diameter.

"I think the evidence is now compelling," says Hildebrand, "that the impact has to be in this part of the world."

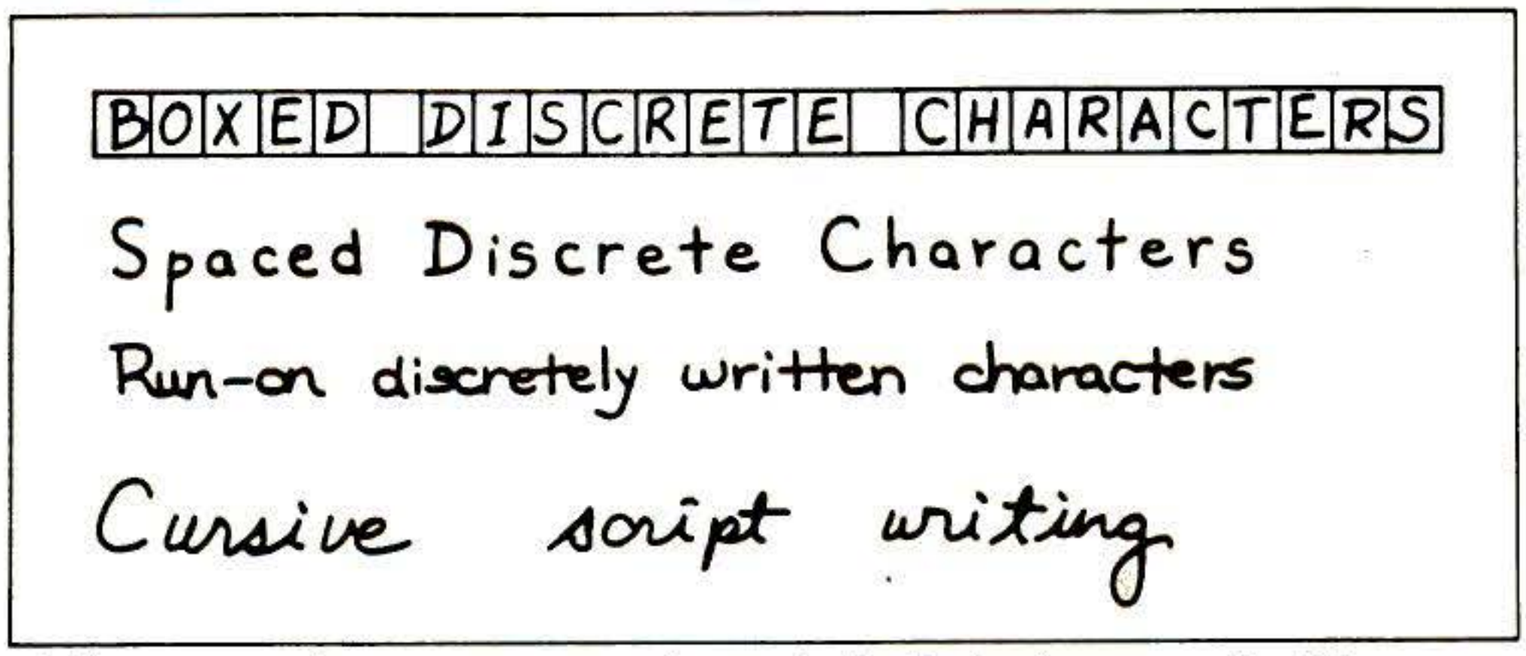
Lightning on Venus

An analysis of radio signal data obtained primarily from the 4,000 or so circuits of Venus by the Pioneer Orbiter spacecraft between 1979 and 1990 show that lightning on the cloud-shrouded planet, once thought to be related to volcanic activity, is probably, like most Earth lightning, related to electrical activity within the clouds.

NASA researcher Christopher Russell compares the radio signals to those generated on Earth when lightning strikes.

"It's as if you are driving in the Midwest and you hear loud static on your car radio. Even if you could not see a thunderstorm, you'd know it was there from the heavy static."

Some space scientists disagree with Russell's conclusions, believing it possible that Pioneer measured local disturbances in Venus's ionosphere instead of lightning. But another member of the radio data team, Robhert Strangeway, says, "The predominance of the data suggests that what we're seeing on the planet is lightning, though there are events that may not be lightning." PS



The first step toward computer recognition of run-on handwriting has been reported by IBM.

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Automotive Newsfront

By DAN McCOSH Detroit Editor *with Dennis Normile in Tokyo, Brian Nadel, and Judith Anne Yeaple*

Navigating in Japan

Motorists in Japan will no longer be able to use the "I got lost" excuse for being late, thanks to a spate of new car navigation systems. Mazda appears to be first to market an electronic navigation system as standard equipment on its home-market Eunos Cosmo sport coupe, while Honda announced that its navigation system is in the final stages of development. The most interesting, though, is a new system designed by Pioneer Electronics Corp. that is now on sale in Japan and can be fitted to any car, new or old.

All three systems rely on digitized maps of Japan recorded on read-only-memory compact discs (CD-ROM); position and direction are shown against a highly detailed map that scrolls across an instrument-panel display. Honda and Mazda chose to use CRT monitors, while Pioneer uses a color flat-screen liquid-crystal display (see photo).

Both Pioneer and Mazda based their systems on the global positioning satellite system (GPS), which uses a network of satellites put into orbit by the U.S. Department of Defense. An antenna mounted on the car picks up signals transmitted continuously by the satellites. An onboard computer calculates the car's position based on the time difference between the synchronized signals. After correcting for slight variations in Earth's roundness, the system's positioning accuracy is said to be within 328 feet.

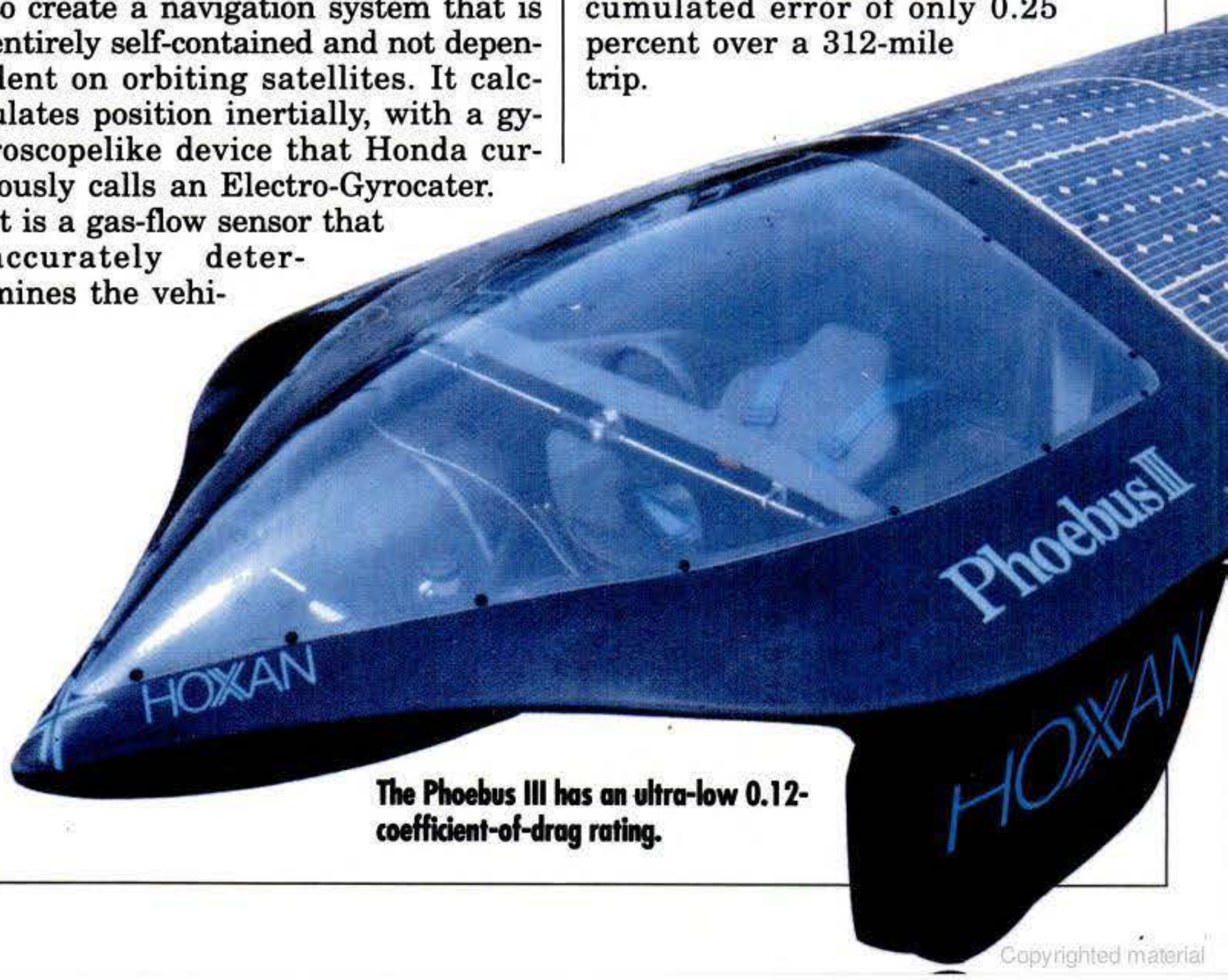
Pioneer thinks this level of accuracy is sufficient to locate the car adequately. The problem is that only half of the full complement of 24 satellites are currently in place, so the navigation screens only function 14 hours a day. The complete network is expected to be fully functioning next year, barring further NASA launch difficulties.

Developed in cooperation with Trimble Navigation Ltd. of the United States, the Pioneer system is integrated into the company's Carrozzeria line of car audio systems. The display also shows which compact disc is currently playing, and the user can enter memos or reminders to be displayed on the screen. When the car is parked, the display can be used as a television if it is connected to the receiver electronics. The Pioneer add-on navigation system sells for $2,300 in Japan.

Lost? Just check the instrument-panel display for the car's position superimposed on a local street map.

Mazda goes further by supplementing the GPS data with an internal dead-reckoning device. The navigation computer has an electronic compass that, combined with speed readings, can independently track the vehicle from a starting point. Periodically the two positions are compared, and any discrepancy is resolved. The screen is used to operate the car's climate control, audio, and a cellular phone.

The Honda navigation system doesn't rely on satellites for its position. Instead, Honda engineers chose to create a navigation system that is entirely self-contained and not dependent on orbiting satellites. It calculates position inertially, with a gyroscopelike device that Honda curiously calls an Electro-Gyrocater. It is a gas-flow sensor that accurately determines the vehicle's direction; its operation is similar to the mass airflow sensors that are used to measure an engine's air intake. As the car is driven, helium emitted from a nozzle inside the Electro-Gyrocater passes over two heated wires. When the car is traveling straight ahead, the gas flows equally over both wires and their temperatures are the same. But, as the car turns, the gas flow shifts, cooling one wire more than the other. The temperature difference is continuously monitored and combined with velocity information from the speedometer to track the car's position from a known starting point. Honda claims this arrangement gives an accumulated error of only 0.25 percent over a 312-mile trip.



The Phoebus III has an ultra-low 0.12-coefficient-of-drag rating.

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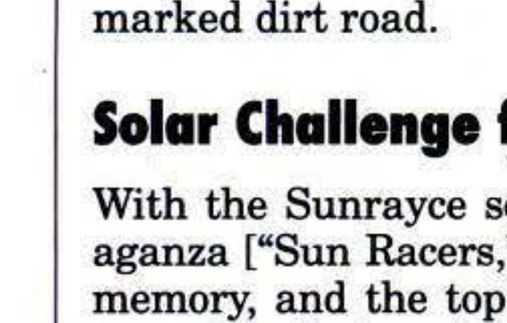
To boost accuracy, it also uses a sophisticated map matching system that continuously compares calculated position with known roads in its memory—good if you stay on roads known to the computer, but useless if you stray onto an unmarked dirt road.

Solar Challenge first peek

With the Sunrayce solar car extravaganza ["Sun Racers," Aug.] a fading memory, and the top three finishers prepping their vehicles for November's World Solar Challenge across Australia, we now get our first glimpse of what the competition will be like. The Phoebus III shown here is the product of a joint development project by two Japanese industrial giants—Hoxan Corp. and Autech Japan—and Japan's Ministry of International Trade and Industry. The car appears to be modeled after the General Motors Sunraycer, which dominated the field in the last trans-Australia solar car race in 1987 ["Chasing Sunraycer Across Australia," Feb. '88]. With a chassis and body made entirely of composites, it weighs in at a mere 336 pounds, some 60 pounds lighter than Sunraycer. The three-wheeled Phoebus III has an ultra-sleek 0.12-coefficient-of-drag rating, which allows it to achieve a cruising speed of more than 62 mph, according to a Hoxan representative. The Phoebus's driving force is provided by an 11-pound brushless direct-current motor rated at a mere 2.7 horsepower; energy is stored in silver-zinc batteries.

The Phoebus is powered by the world's most efficient production solar cells, according to Hoxan. This could be enough of an advantage to keep the other competitors in its shadow on the 1,900-mile route from Darwin to Adelaide. While most of the competitors probably will have to make do with commercially available solar cells that are, at best, 15 percent efficient in converting the sun's rays to electrical current, Hoxan has covered its car with 1,820 cells that are 19.3 percent efficient. This gain is a result of using state-of-the-art microelectronic processing techniques and reducing the width of electrical connections to 100 microns, exposing more of the electricity-generating silicon surface to the sun.



This is not Hoxan's first attempt to drive across Australia powered by the sun. In 1987, the company's team finished 11th overall in the World Solar Challenge, the highest-placing Japanese entry.

From home to car

Natural gas makes a great fuel for cars, being inexpensive and clean-burning, but drivers have been slow converting to it due to limited availability. Part of the reason, speculates Sam Blundell, sales manager for FuelMaker Corp. of British Columbia, Canada, is that compressed natural gas has been restricted to fleets large enough to make expensive refueling stations economically viable. At present there are about 30,000 natural-gas-fueled vehicles in the United States. Now the company is offering the most convenient natural-gas refueling system of all: a refueling appliance that can be installed in the driver's own garage.

The FuelMaker is a picnic-cooler-size unit that draws fuel from the natural-gas pipeline connection already installed in many homes for cooking and heating. To use it, simply attach FuelMaker's hose to the vehicle's refueling connection and start the machine. FuelMaker automatically feeds the gas directly into the tank until it reaches 2,900 psi—the maximum pressure—then shuts itself off. Because utilities' systems are designed for appliances that consume natural gas at a slower rate, FuelMaker needs approximately five hours to refill the typical car's natural-gas tank completely.

FuelMaker relies on a four-stage air-cooled compressor driven by an electric motor and monitored by a microprocessor-based control system. Safety features have been programmed into the unit, including an automatic shut-off function if it senses a sudden pressure drop due to a

SECOND-GENERATION MINIVAN

PREVIEW DRIVE

Three cheers for Chrysler Corp.: When the time came to update its best-selling minivans, engineers and designers limited themselves to fixing what was wrong and left the rest alone.

Because the exterior styling remains familiar, there's little chance of confusing the new Plymouth Voyager, Dodge Caravan, or Chrysler Town & Country with the latest from Japan. But every sheet-metal panel (except for the roof) is new for '91, each edge and crease having been softened. In fact, 80 percent of the van's major parts have been redone, starting with an interior refurbishing and working all the way to the front suspension hardware. And the standard bearer of the minivan class now is available with antilock brakes, a heavy-duty handling package, second-row bucket seats, and four-wheel drive.

The all-wheel-drive system uses a viscous coupling between the front and rear differentials to give full-time, fully automated operation. The hardware, from Austria's Steyr-Daimler-Puch AG, has been adapted to the standard leaf-spring and beam-axle rear suspension of the front-drive minivan. The AWD system, which is available with ABS, adds 300 pounds to the gross weight, decreases fuel economy by one mpg, and will add $1,800 to the price.

What owners will most appreciate is the interior layout, with a neater instrument panel and a badly needed relocation of the radio and remote mirror controls. There's a glove compartment in the instrument panel now, in addition to the underseat storage bin. Safety ranked high on customer wish lists, so a center stop lamp and rear headrests were added.

Drivers hankering for more-precise handling will notice the chassis refinements right away. Highway stability is improved and cornering is more confident thanks to increased front wheel caster, a higher front roll center, and reduced bump steer effect; and the steering is tighter thanks to a zero-lash coupling. The optional heavy-duty handling package adds a link-type rear sway bar, bringing the Chrysler minis to a much-improved level of roadworthiness.—*Norman S. Mayersohn*

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Automotive Newsfront

severed hose or disconnected nozzle. The microprocessor even compensates for the weather. "If it's forty degrees below zero outside, the appliance will only fill the tank to 1,600 psi," explains Blundell. This limitation keeps the gas from expanding beyond the tank's capability when the temperature rises.

At about $3,000 per unit, the FuelMaker isn't cheap. According to Blundell, one Canadian utility has already announced a $50-per-month rental program.

CNG trucks

Compressed-natural-gas-powered cars are not the only alternate-fueled vehicles receiving attention these days. General Motors recently announced it would build at least 1,000 CNG-powered GMC Sierra full-size pickup trucks for sale to the general public. The main selling point for these vehicles will be lower emissions of reactive hydrocarbons, principle contributors to the formation of smog. On top of burning fuel more completely and sending fewer pollutants out the tailpipe, natural gas does not release any evaporative emissions during refueling or in use.

Methanol hot rod

Making the most of methanol for a production car at first appears straightforward and easy ["Clean-Air Fuels for the '90s," Jan.]. Even when diluted with 15 percent gasoline in a fuel called M-85, its high octane level

STYLISH STYLUS

PREVIEW DRIVE

There are more than 50 subcompacts currently on sale in the United States, but two from Isuzu—the Impulse coupe and the new Stylus sedan—are the first in this class to offer a driver's-side air bag. That's not the only distinguishing feature of the Stylus, a small car that will try to bite off a chunk of the huge (about two million sales annually) subcompact car market.

Isuzu temporarily dropped out of the U.S. car market when it discontinued the I-Mark model in 1989. The Stylus attempts to re-establish Isuzu's presence. The grilleless Stylus has pleasing lines that include integrated flush modular headlights.

At 89 cubic feet, the Stylus is one of the roomiest subcompacts we've had an opportunity to test drive. Even Toyota's Camry, which is classified as a compact, has slightly less interior space than the Stylus, though a larger trunk. When I tested the model in the mountains north of Santa Barbara, Calif., the road-holding ability and acceleration displayed by the Stylus buttressed my impression that this is not just another entry-level car.

The Stylus S is equipped with a standard 12-valve single-overhead-cam 1.6-liter engine that does not appreciably vibrate or sound buzzy, even when accelerating uphill at full throttle. The Stylus XS comes with a 16-valve twin-cam engine. The four extra valves help it produce 130 hp, compared with the 95 hp of the base engine. The XS also comes with a Lotus-tuned suspension for an even sportier ride than the base model. The suspension is an admirable compromise for a subcompact car: taut enough to minimize body roll around corners, yet forgiving of bumps. The five-speed gearshift is smooth and precise through all ranges. (A three-speed automatic is an option.) The Stylus S is $9,199 and the XS is $11,299.—*Herbert Shuldiner*

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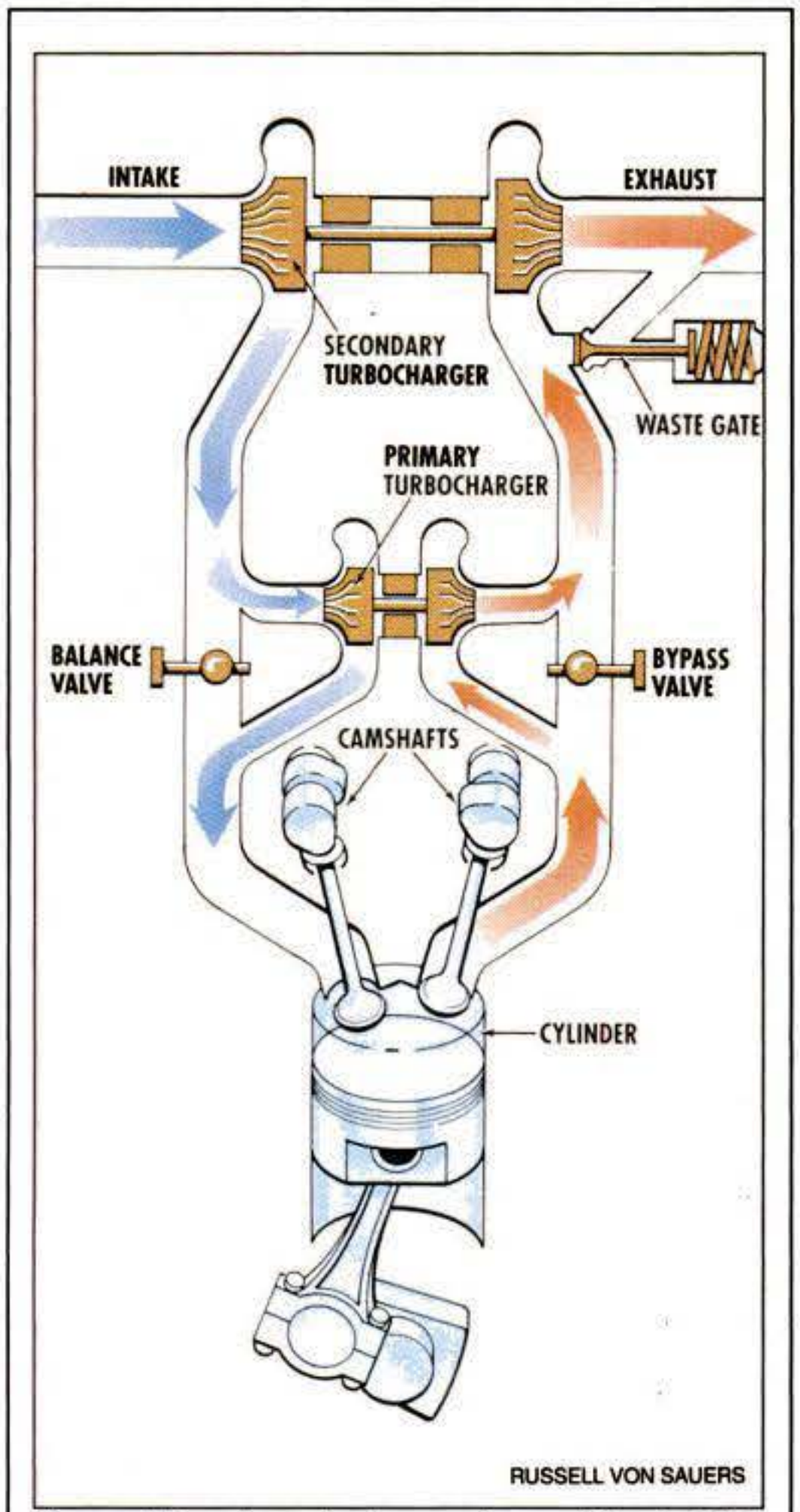

Sequential twin turbochargers boost Volvo's 2.5-liter Methanol Environmental Performance engine to nearly 300 hp.

can lead engine designers to increase compression ratio to upward of 12:1 without the danger of knocking. Now Volvo is taking a different approach to extracting maximum output from methanol fuels—a dual-turbocharged in-line six-cylinder engine that meets the tough California emissions standards scheduled to take effect in the year 2007 ["Commanding California's War on Smog," Sept.].

Called MEP, for Methanol Environmental Performance, the 2.5-liter engine delivers a startling 272 hp and an even more remarkable 295 lb.-ft. of torque. A newly designed two-stage turbocharging system is the key to the power output. With the help of 110-octane cool-burning M-85, a 10:1 compression ratio can be used without the danger of engine-damaging detonation.

As shown in the drawing, the sequential turbo setup uses a small primary turbo for quick response, joined by a larger turbo as engine speed rises. The first turbine has a low rotating mass, enabling it to deliver boost at engine speeds as low as 1,000 rpm. By 1,200 rpm the larger secondary turbine spins into action; at 2,000 rpm the computer controller smoothly opens a bypass valve in the

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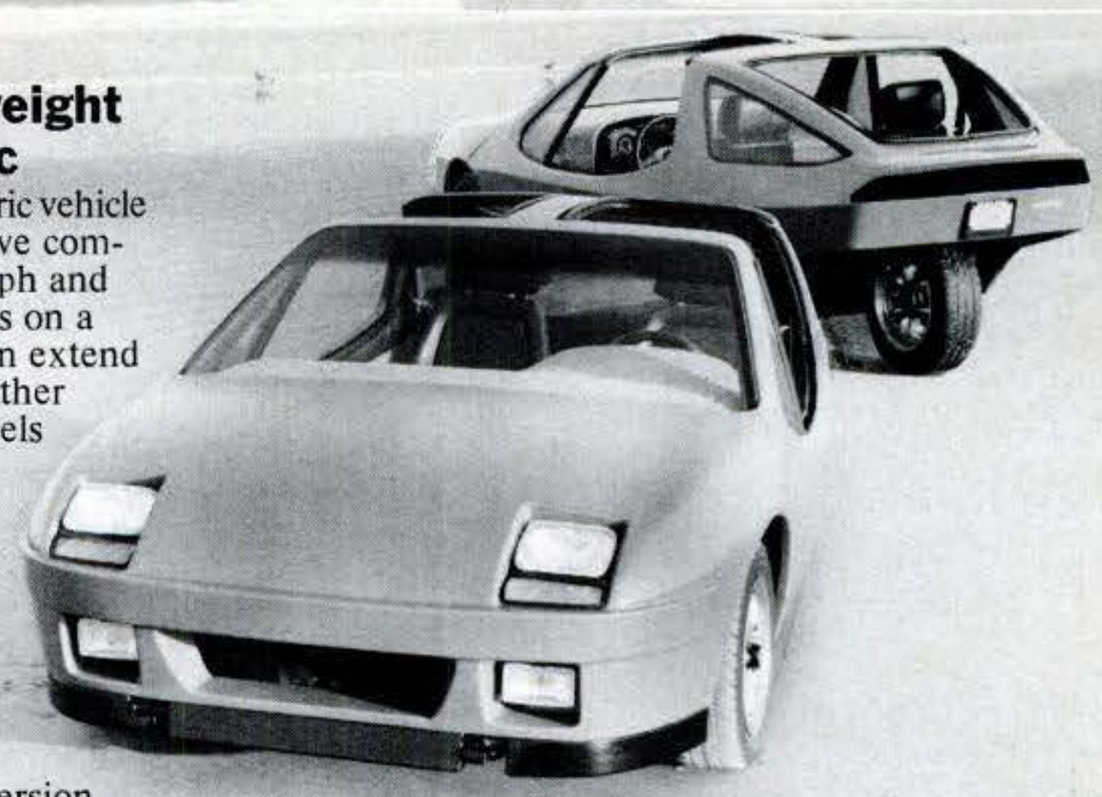

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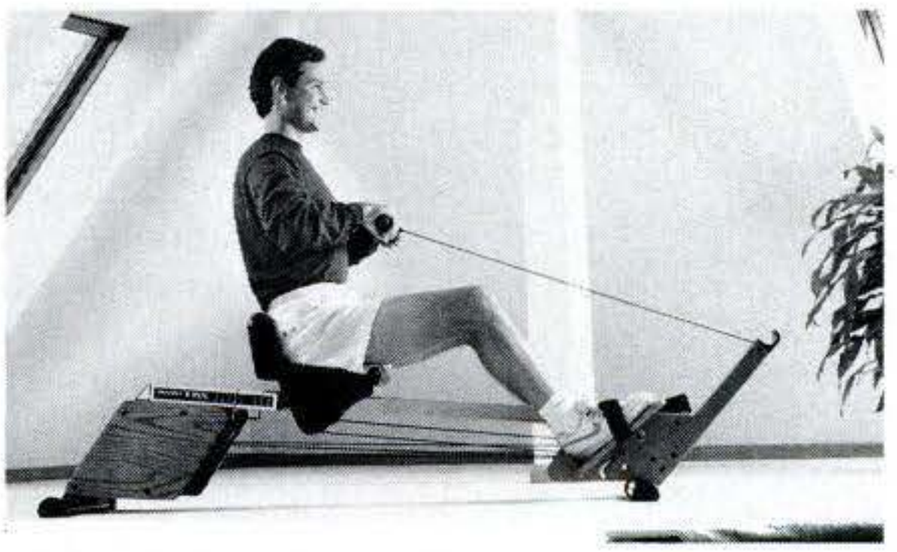

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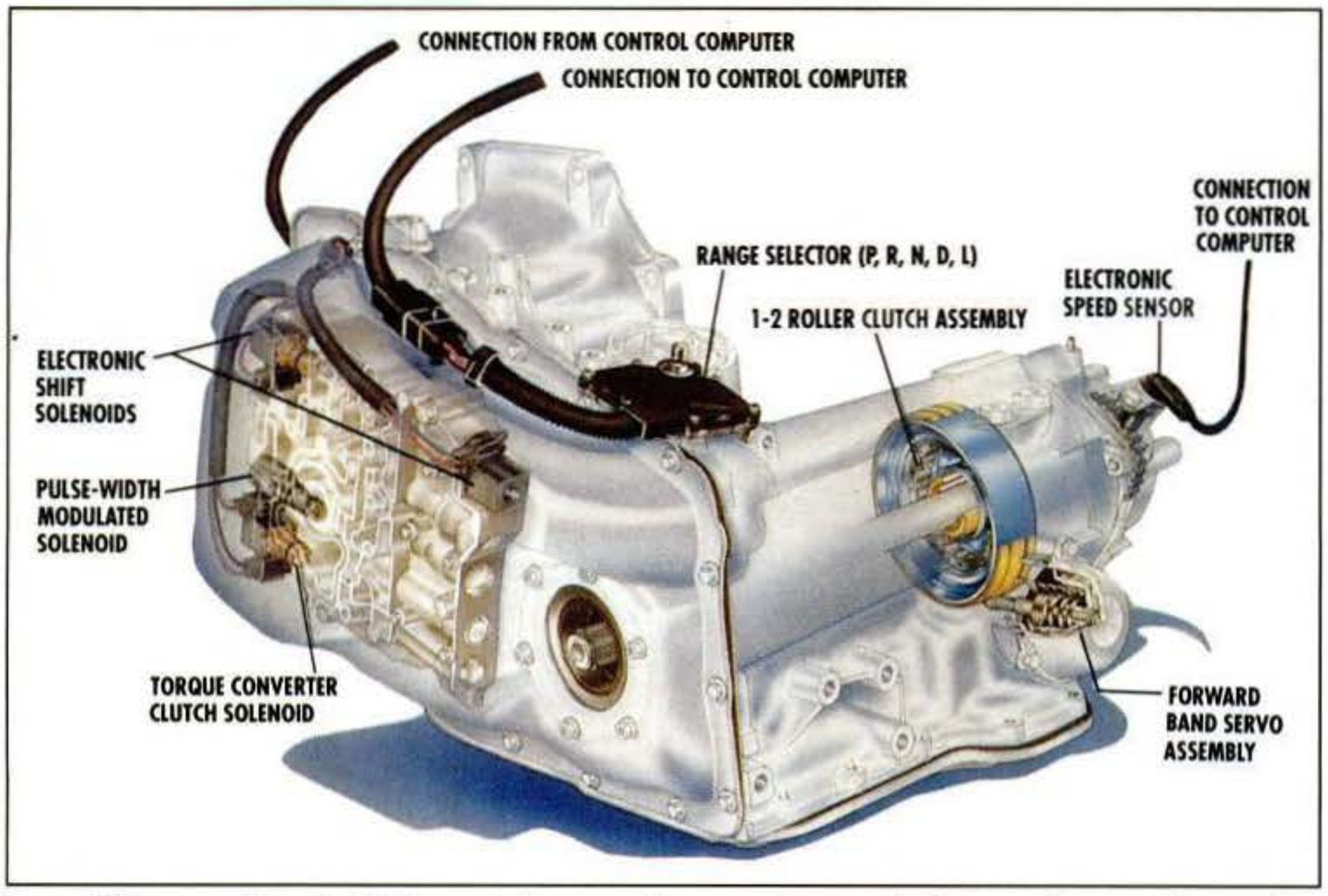
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TORQUE CONVERTER CLUTCH SOLENOID
FORWARD BAND SERVO ASSEMBLY

General Motors updates its Hydra-matic four-speed automatic transaxle for smoother gear changes by controlling all shifts with the engine management computer and shift solenoids.

exhaust pipe, sending the exhaust gases directly to the secondary turbine for maximum output. At the same time, a spring-loaded valve on the air-intake side automatically opens to remove the small primary turbo from the loop.

A variation of Volvo's muscular two-stage turbo concept is also used on a three-liter in-line six that has separate low-inertia turbochargers in parallel, one for each group of three cylinders. Running on 95-octane unleaded gas and breathing through a four-valve-per-cylinder head and an intercooler, this engine belts out 273 hp and 295 lb.-ft. of torque.

On an abandoned airfield near Volvo's headquarters in Gothenburg, Sweden, a pedal-to-the-metal experience with a 760 model fitted with the experimental engine revealed no throttle lag and a 0-to-100-kilometers-per-hour (62 mph) time of 7.2 seconds. Sources say either of these two powerhouses could be in production in three years.

Intelligent shifting

Theoretically, an electronically controlled automatic transmission allows each gearset to be engaged at exactly the right moment, optimizing shift feel and efficiency. This level of precision has led many of the world's auto makers to adopt this technology. So it came as something of a surprise that General Motors' new electronically controlled Hydra-matic 4T60-E transaxle retains the principle feature of older all-hydraulic designs —one-way overrunning clutches controlling each gearset. It seems that the General Motors engineers are not entirely convinced electronics are as quick or as smooth as one-way clutches in letting go of one gear before grabbing the next. The result is a design that at first appears cumbersome and Byzantine. For the typical upshift, a pulse-width modulated solenoid engages the higher gear as the one-way roller clutch releases the lower ratio (see illustration). The engine management computer monitors throttle position, vehicle speed, and temperature, and decides every 25 milliseconds whether a shift is called for. In addition, the computer will retard spark timing during gear changes, reducing torque output to soften the gearshifts.

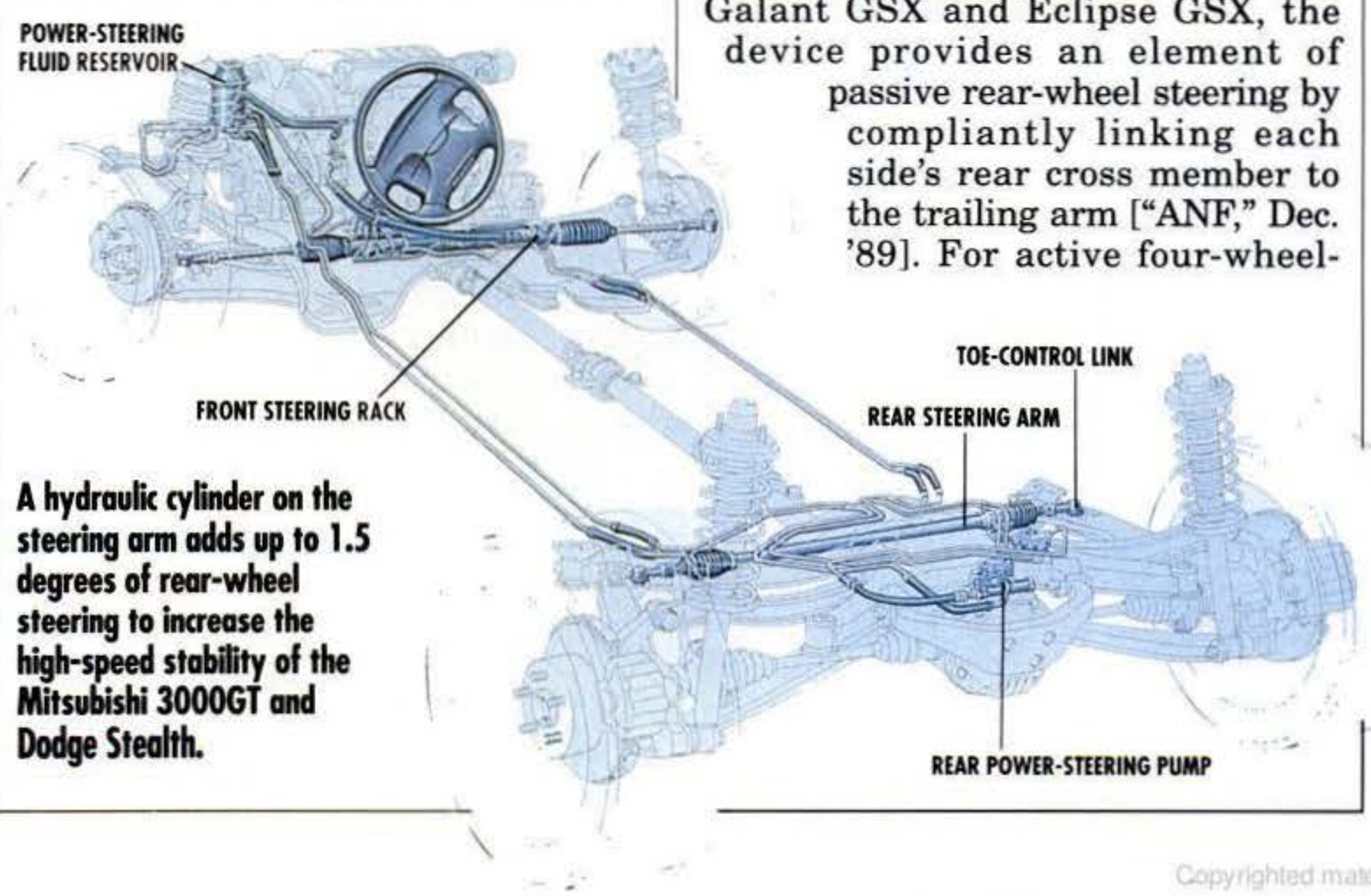
There is some penalty in weight and bulk, but the system promises improved reliability and smoothness, according to GM's Hydra-matic division. The redesigned transmission is rated to handle a maximum of 235 lb.-ft. of torque, which leaves enough leeway for using it with GM's new 3.4-liter quad-cam V6 (see "Detroit Shifts the Balance of Power," this issue).

All-wheel drive, all-wheel steer

Keeping 300 hp under control was the goal of Mitsubishi engineers who developed the power train for the Dodge Stealth and Mitsubishi 3000GT sport coupes. The power output of the 24-valve twin-turbocharged V6 makes it one of the few cars that can utilize the additional traction of full-time four-wheel drive on dry pavement. In addition, a four-wheel steering system stabilizes high-speed maneuvers for improved handling.

Neither choice is new, but the system represents some new thinking in both arenas. Four-wheel drive is achieved through a planetary center differential separating the front and rear axles. A viscous coupling offers a limited-slip feature, which comes into play when one axle loses traction. It's a popular design, but because it works only after the onset of wheelspin, it can upset the power balance between the wheels. Mitsubishi approaches the problem by taking the rear drive directly from transmission output, which turns at three times axle speed. The result: a system that is more sensitive to the loss of traction because less wheel slip is needed to activate the viscous coupling.

A similar approach aimed at stability and finesse is taken with the car's four-wheel steering system. Rather than design a rear-wheel steering system from scratch, Mitsubishi engineers used the company's highly effective toe-control link as a starting point. On the all-wheel-drive Galant GSX and Eclipse GSX, the device provides an element of passive rear-wheel steering by compliantly linking each side's rear cross member to the trailing arm ["ANF," Dec. '89]. For active four-wheel-



A hydraulic cylinder on the steering arm adds up to 1.5 degrees of rear-wheel steering to increase the high-speed stability of the Mitsubishi 3000GT and Dodge Stealth.

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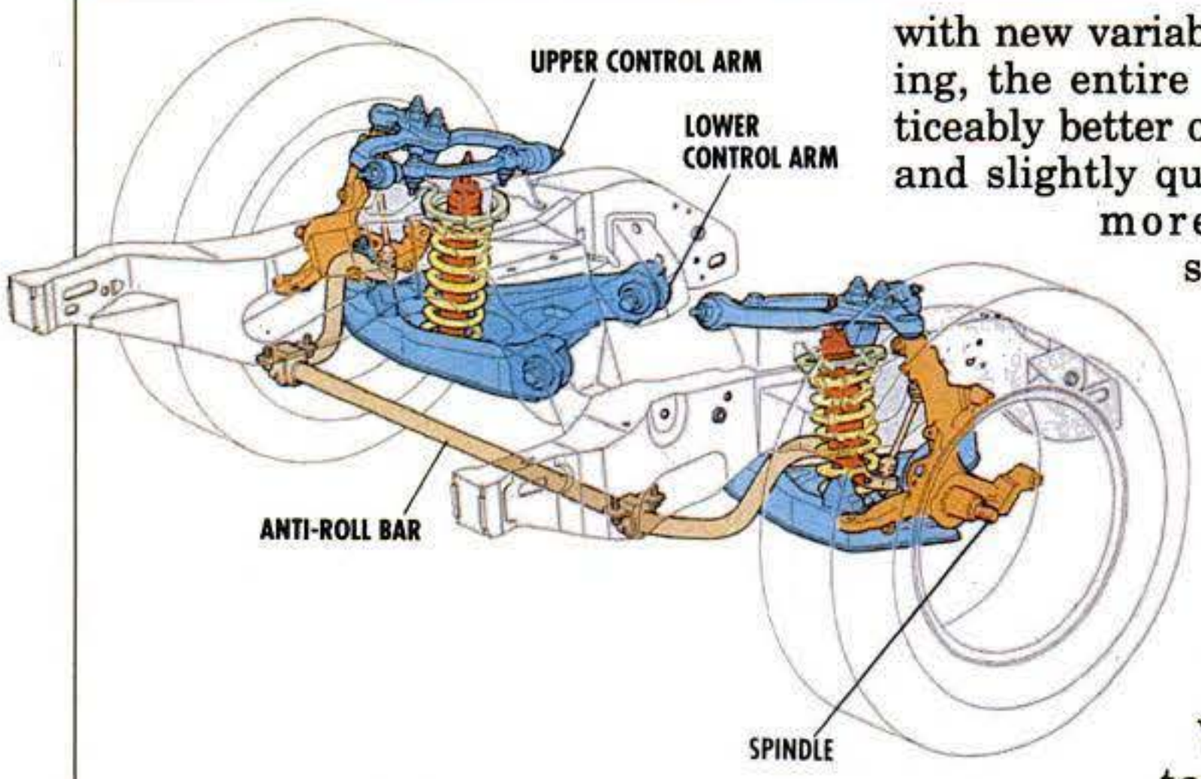

A redesign of the Town Car's upper control arm, anti-roll bar, and spindle improves the luxury car's ride and handling.

steer models, a hydraulically actuated power cylinder is added to control a steering arm connected to the toe link. A power-steering pump driven by the rear differential is used, which makes it possible for the pressure to be varied according to the car's speed.

Starting at 30 mph, the system provides progressively more rear-wheel steering input to a maximum of 1.5 degrees in the direction of the front wheels. The real benefit of this technology is the reduction in the tail-wagging experienced during rapid lane changes. The Mitsubishi system provides extremely precise control over the car, allowing the driver to slither through turns at high speed. On the negative side, by steering all four wheels the car can at times feel twitchy and oversensitive, with every slight steering input translated into a change in direction.

Controllable limos

Taken separately, the new front-suspension bits and pieces on the 1991 Lincoln Town Car don't appear especially significant, but together they further refine this recently updated luxury sedan. The front axle gets a new upper control arm, spindle, and an anti-roll bar to increase caster angle and roll control (see illustration above). Another benefit of the redesign is that technicians can now adjust front-end caster and camber angles independently. This is tied to a new computerized alignment procedure at the factory that allows more precise settings.

All this doesn't put the big Lincoln in the sports car category, but along with new variable-assist power steering, the entire setup makes for noticeably better on-center steering feel and slightly quicker turn-in. Even more noticeable is the solid feel of the new standard four-wheel disc brakes; new options available for '91 include antilock brakes and a traction-control system.

Brave Bravada

With some reluctance, Oldsmobile acknowledges that few owners of four-wheel-drive sport utility vehicles ever venture off urban and suburban roads. So Olds engineers completely redesigned the four-wheel-drive system of the Chevrolet Blazer-based Bravada, producing a utility vehicle more appropriate for the country club set than a park ranger.

Bravada's basic mechanical components are taken from the all-wheel-drive Chevrolet Astro minivan parts bin: 4.3-liter V6 engine, a full-time transfer case that uses a planetary center differential to divide torque between the front and rear wheels, and a viscous coupling to limit slip. This allows the system always to be engaged, as opposed to the Blazer's part-time four-wheel drive. Bravada also is one of the few trucks on the market that has both four-wheel drive and four-wheel antilock brakes. Finally, the suspension was retuned to give a softer ride. And the Bravada does seem to handle washboard roads and potholes with far less wheel hop and chatter than most hard-case sport utilities. The result is a far more refined and drivable package than most vehicles in this class. This is not to say that comfort has been achieved at the expense of off-road prowess, because we had no trouble climbing a rough trail in sand. PS

NEW NISSAN SENTRA

Nissan's sweeping overhaul of its model line has finally trickled down to the entry level: For 1991 the Sentra gets an all-new replacement. Designed to vie in the hotly contested small-sedan category, the new Sentra's shape is conservative, but not unappealing.

The reborn Sentra comes with a choice of 16-valve DOHC fours in 1.6-liter 110-hp or two-liter 140-hp trim. Nissan focused development work on giving these engines broad powerbands while maintaining good fuel economy. The cars we drove both had prototype engines installed, with the larger one being much closer to the final production configuration. The difference showed: The revvy 1.6-liter engine, which features variable intake-cam timing and develops 108 lb.-ft. of torque at 4,000 rpm, buzzes a fair amount in the higher rpm ranges. By contrast, the all-aluminum two-liter engine generates silky, energetic pulling power throughout the rpm range, with its 132 lb.-ft. torque peak occurring at 4,800 rpm.

Finding power and tractability in an engine while keeping its appetite for fuel under control is a subtle business. According to Nissan engine designer Makoto Yasuda, major gains resulted from the development of remarkably long large-diameter intake runners with tapering interior diameters. This intake tract design efficiently boosts low- and medium-speed power by keeping intake-air velocity high and creating a strong resonance effect that helps ram the air-fuel mixture into the cylinders. With a five-speed manual transmission, the 1.6-liter engine earns EPA fuel economy estimates of 30 mpg in the city and 39 mpg on the highway; the two-liter motor rates 24 and 32 mpg, respectively.

Mated to a slick five-speed transmission in the SE-R performance version, the bigger engine makes for brisk acceleration and effortless cruising.—*Stuart F. Brown*

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Electronics Newsfront

By WILLIAM J. HAWKINS *with John Free, Robin Nelson, David Scott in London, Dawn Stover, and Judith Anne Yeaple*

PCs come home again

With introductions from two of the biggest computer makers—IBM and Tandy—we may be on the verge of a jump-start for the erstwhile era of home computers.

A "home" computer? That's been tried before... and failed miserably. Remember the PCjr and Coleco's Adam? But something is different. To aim squarely at the home user, both companies are playing down technology, hyping ease of use.

All the programs that come with these machines are ready to run instantly: Software on diskettes is already programmed to use all the computer's hardware, and if you buy a model that contains a hard disk, all the programs are loaded and ready to go. The idea: If you can set up a toaster, you can use these "appliance" computers.

For example, open the box of IBM's new PS/1, and the instruction manual is on top, opened to the page that tells you what to do next: Plug the monitor into a wall outlet, the system box into the monitor, and turn on the power. The machine is instantly taken over by the built-in-operating system (DOS 4.01) and the User Interface Program. There are no commands to type or special characters to remember to get things done. Instead, the display shows a graphic quadrant of selections from which to choose with a mouse:

- "Information" about the system, tutorials, and on-line help.
- "Microsoft Works" containing spread sheets, data bases, word processing, and communications.
- "Your software" for choosing programs you've added to the computer.
- "IBM DOS" for menu-driven commands that use the operating system for such things as copying files or formatting disks.

Pick one of the four areas, click the mouse, and the PS/1 becomes a clever combination of graphics and on-screen easy-to-follow instructions. But if you still get confused?

"Call us," says Robert Amezcua, product manager for IBM. He's not kidding. IBM has a toll-free hot line for assistance, and once you become accustomed to using the computer, you can use its built-in modem to get general information about the PS/1 over the Prodigy and Promenade computer networks.

Screen to screen: Tandy's 1000 RL computer (top) and IBM's PS/1 (above) are both designed specifically for the elusive "home" market.

While IBM won't tout technology in the PS/1 (Amezcua calls it the "T" word), it's a powerful machine, and even the basic $999 model includes everything you need to get started: a 10-megahertz 80286 processor, 512 kilobytes of RAM (expandable to one megabyte), a 1.44-megabyte 3.5-inch diskette drive, a 12-inch VGA monochrome monitor, a full-size keyboard, a mouse, a 2,400-bps modem, and software. A high-end $1,999 model has a color monitor, a 30-megabyte hard drive, and one megabyte of memory. And a $169 Adapter Card Unit, which mounts between the console and monitor, is available for adding additional circuit boards—fax or scanner, for example—to the system.

If you're looking for an even less expensive machine, Tandy's 1000 RL starts at $750. It includes a monochrome CGA monitor, 512 kilobytes of memory (expandable to 768 kilobytes), a 3.5-inch diskette drive, two joy sticks, software, and a mouse. A 16-color CGA model with a 20-megabyte hard drive is $1,299. While the computer runs any PC-compatible software, the 80286-based machine concentrates on new, truly home-oriented applications.

For example, the Home Information Center program is an electronic bulletin board: Leave and retrieve messages for others in the family on the computer. "It's designed to be on all day," explains Tandy spokesman Ed Juge. "The screen blanks out and the hard disk stops after five minutes of no activity." That saves power (Juge claims that when the computer is in standby mode it draws only as much current as a clock radio), but it also means the computer is available instantly for use. Touch a key, and the message reappears.

Also, there's a Home Organizer program, which is divided into three different categories: personal, kitchen, and financial. Under those areas you can organize lists, balance your checkbook, and plan meals based on recipes from an electronic version of *The Good Housekeeping Cookbook*. "It will adjust the recipes depending on how many guests you're having," claims Juge, "and even make up a shopping list of ingredients you'll need."

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Electronics Newsfront

Phony alarms

Kansas policemen reportedly receive several calls a month from cordless phones that dial the 911 emergency number when their batteries deteriorate. Apparently, the dying phones emit spurious signals that include a call for help.

Factor to consider

Factoring a number requires finding the prime numbers that divide it (prime numbers are only evenly divisible by one and by themselves). For example, the number 105 is factored into 3x5x7. As the number to be factored gets larger, determining its prime numbers becomes much more difficult. That's why present digital encryption systems, used to code secretly everything from government messages to bank transactions, rely on a 155-digit number. Factoring that number, called the ninth Fermat, has been considered impossible by present techniques, making the data it scrambles secure from unauthorized eyes.

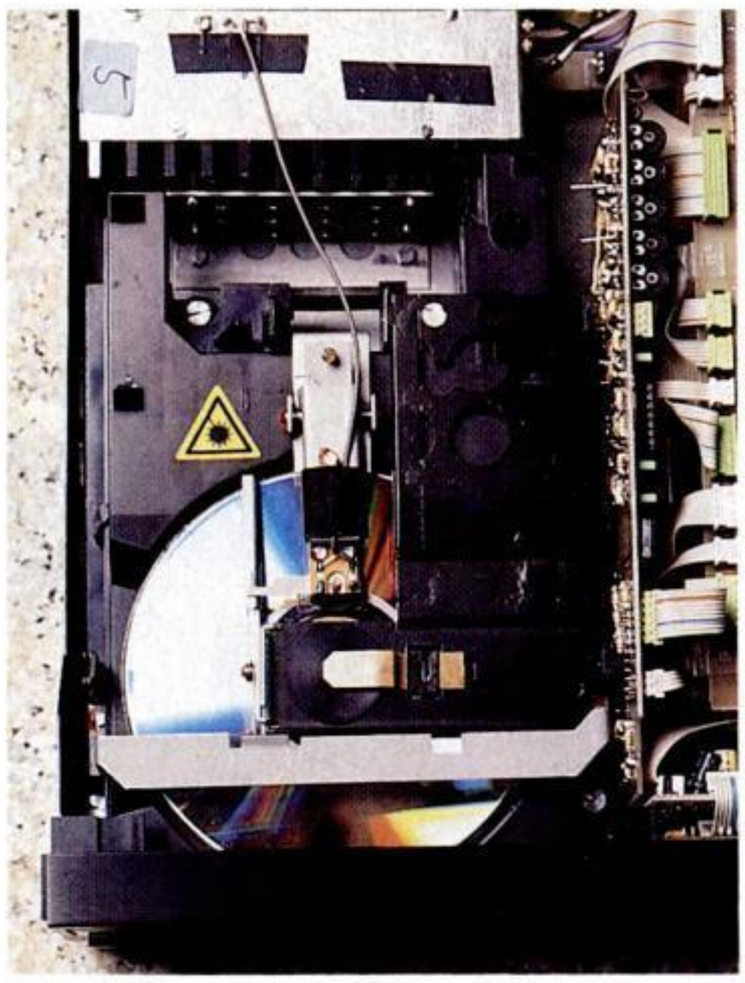
Now, warn researchers Arjen Lenstra, from Bellcore, and Mark Manasse, at Digital Equipment Corp., better make that a 200-digit number. The two scientists have factored the 155-digit number using a network of almost 1,000 computers that stretched through the United States, Europe, Australia, and Japan. Using the network at night, during off hours, it took a few months to determine the answer: The factors are three numbers that are 7, 49, and 99 digits long. Lenstra calculates that if you tried doing the same calculations full time, on a medium-powered computer performing one million operations a second, it would take about 275 years.

Erasable CDs

Slide a compact disc into an unusual player at a Thomson Consumer Electronics' showroom and "CD" appears on its green alphanumeric display. Put a similar 4.7-inch disc with a glossy brown coating into the machine and the letters "MOD" appear. The MOD—magneto-optical disc—lets you record up to five hours of digital audio on Thomson's DR 1000. Only five similar machines exist, but developer Deutsche Thomson-Brandt of Villingen, West Germany, hopes that millions of similar disc recorders will appear in homes during the 1990s.

The DR 1000 is an intriguing gadget. Put an ordinary music CD into the machine and you'll hear superb audio. Plug a separate CD player into the DR 1000 and you can make exact disc copies—every digital one or zero stored on the originals—onto MODs. You can also erase and rerecord MODs endlessly. One drawback is that your disc recordings won't play back on today's CD players. But with a few modifications, future CD players could play MODs.

The latest DR 1000 prototype simplifies recording by using audio signals to vary the magnetic field from a dime-size coil above the MOD (see photo) with the audio signal. A laser beam beneath the disc that was formerly modulated with audio now heats and erases the magnetic coating. The previous technique, pulsing the laser with audio, required a separate pass to erase audio tracks.



The disc-drive section of Thomson's CD recorder captures up to five hours of audio.

Thomson isn't sure when MOD machines will be in stores. "What will slow down the introduction of this machine are the copyright issues and our ability to get other manufacturers—both hardware and software—on board with this system as a standard," says Daniel Collishaw, manager of audio product development at Thomson in Syracuse, N.Y.

Coming: no-miss VCRs

It's galling when you carefully program the VCR to record your favorite TV show, then return home to find that the broadcast ran late. Result: The VCR started early—and stopped early—so you never find out if the butler really did do it. Britain's TV Channel 4 aims to eliminate this annoyance by transmitting unseen coded teletext signals that would automatically start and stop waiting VCRs at exactly the right time despite any change in schedule. The system, being tested early next year, requires a new generation of VCRs incorporating the necessary teletext decoder, and Channel 4 is spearheading the idea as a means of gaining viewers for its own programs.

Similar schemes are being tried in Europe, and in the United States the Electronic Industries Association is trying to create standards for the variety of ways information can be sent via broadcast or cable systems used in the home. Future VCRs could be set to record, say, all mysteries—then you'll know all the butlers that did it.

Digital sound at the movies

Cinema Digital Sound (CDS) is the latest in motion picture audio technology. Developed jointly by Eastman Kodak Co. in Rochester, N.Y., and Optical Radiation Corp. in Azusa, Calif., CDS is a six-channel digital soundtrack that provides a dynamic range equal to compact discs. And unlike the best analog soundtracks, rated at 30 to 14,500 hertz, CDS has a wider frequency range too, from 20 to 20,000 hertz.

CDS relies on Kodak's new sound recording film to store digitally the information in the optical soundtrack. Although theaters need a new sound processor, the device mounts on existing projectors. Already two New York theaters and five Los Angeles theaters are equipped to play CDS, and one movie, *Dick Tracy*, has the digital soundtrack.

The inventors say the exceptional audio should lure people away from their VCRs and back to the theaters. As one Kodak official explained, "What you hear is much more like what the creator intended."

Dealers take a RISC

Sun Microsystems is the first desktop work station manufacturer to offer a RISC-based (Reduced Instruction Set Computing) machine through local computer dealers. The RISC microprocessor design, which accepts only a few software instructions, concentrates on speed: The new $9,995 color work station, called the IPC SPARCstation, operates at 15.8 mips (millions of instructions per second). That's significantly faster than top-end personal computers such as Apple's $15,000 Macintosh IIfx (eight mips); slightly faster than Intel-based

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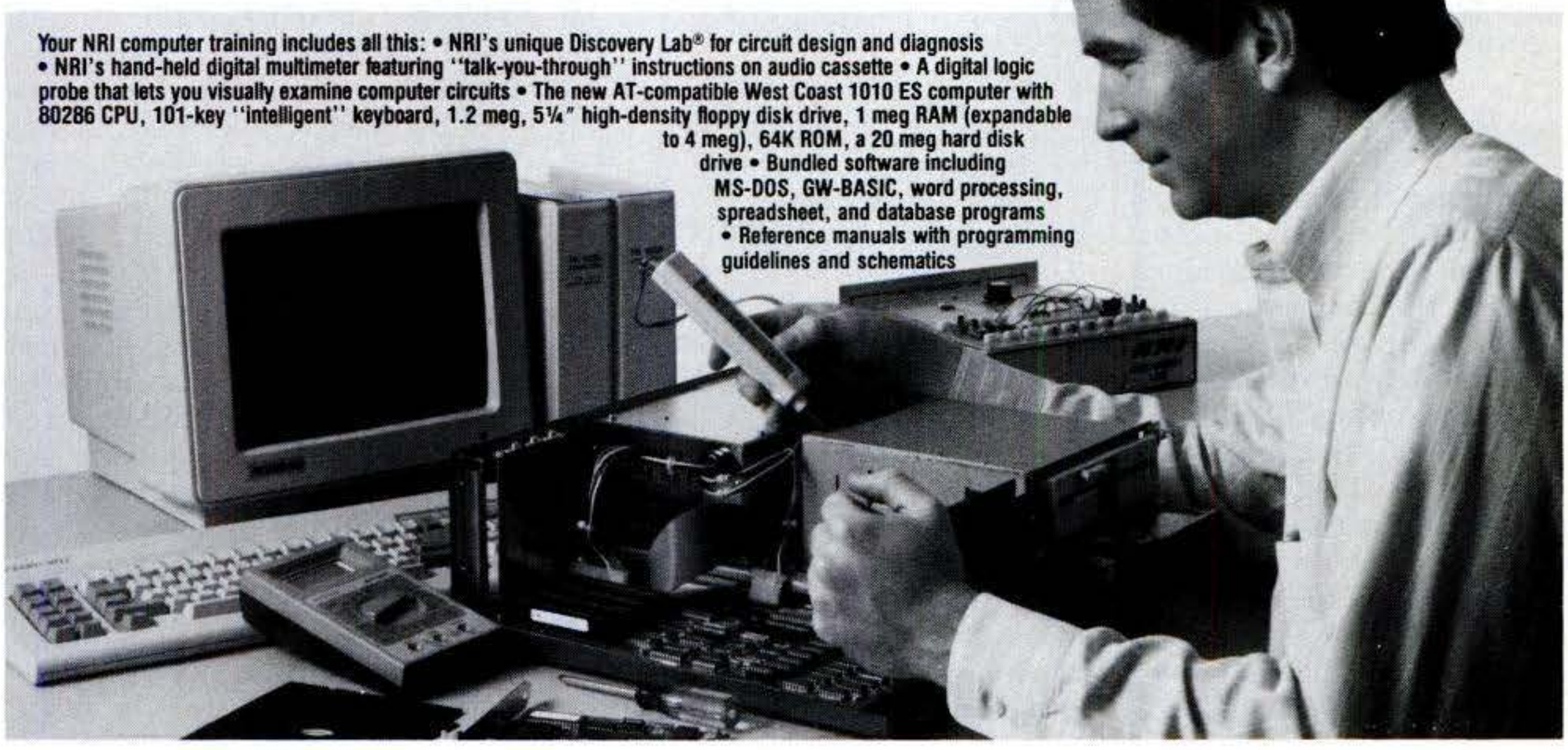

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personal work stations like Compaq's 15-mips DeskPro 486/25 that would sell, similarly configured, for almost $10,000 more. The system includes a 207-megabyte hard disk and a 16-inch color high-resolution monitor (1,152 by 900 pixels). While 16 mips is about 10 more than the average personal computer user ever needs, professionals using computers for publication layout and graphics design should be able to find instant work for the speedy, yet relatively inexpensive, RISC-based system.

Heal thyself

Sometimes, during the manufacturing of circuit boards, electrical paths between integrated circuits become too thin, making the connections unreliable. The "near-open" wiring, called constrictions, are difficult to find and time-consuming to fix. One technique is to use pulses of high current to open any constrictions—like blowing a fuse—making them easier to locate and repair with solder.

But C. Julian Chen of the IBM T. J. Watson Research Center has invented a form a electroplating that lets constrictions repair themselves. To do it, a carefully controlled AC current is passed through the metal path, which is placed in a plating solution (see drawing). Because a thinner electrical path will have greater resistance, any constrictions will begin to heat causing a deposition process—the constriction is plated with metal that is transferred from cooler areas of the path in the plating solution.

The technique repairs multiple constrictions at once and even stops automatically—once a constriction is plated sufficiently, its resistance drops, which reduces the heat and stops deposition.

Go-anywhere cellular phone

Motorola is developing a satellite-based system that will allow callers in remote areas of the world to communicate by telephone. "You will be able to dial one number to reach someone, even if you don't know where they are on Earth," declared John F. Mitchell, vice chairman of the company, at a recent news conference.

Mitchell says the proposed system will use "a constellation of seventy-seven lightweight satellites in low-Earth orbit." The system is called Iridium, after the element iridium, in which 77 electrons orbit the atomic nucleus. The Iridium satellites will travel in polar orbits 413 nautical miles above Earth, low enough to transmit signals to phones equipped with small antennas. Because of the large number of satellites, at least one will always be in view.

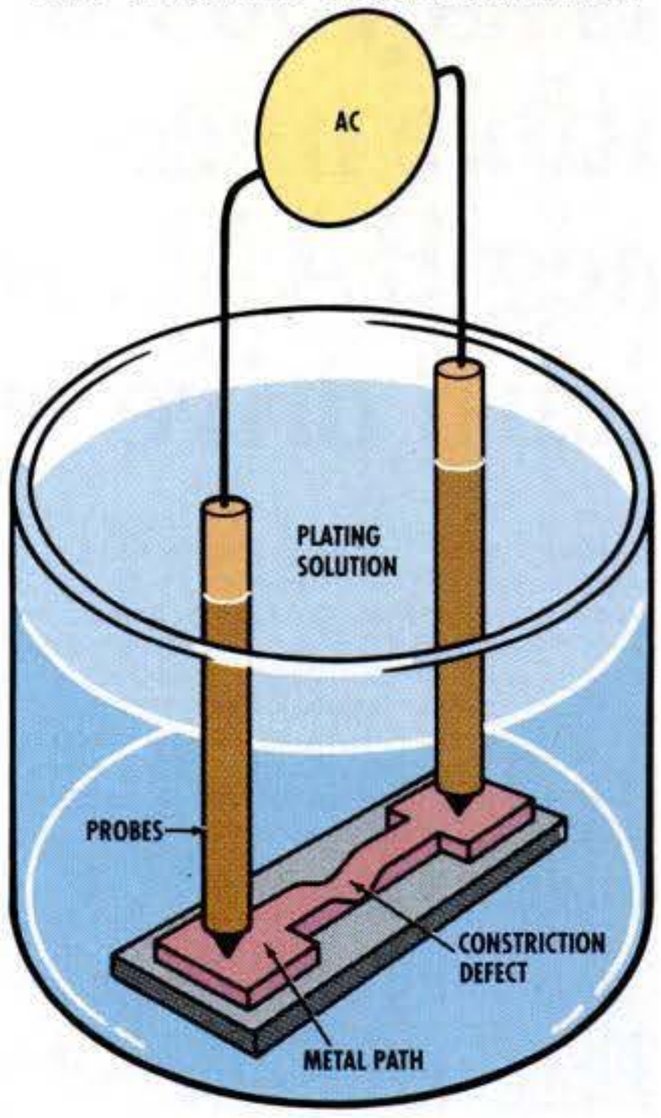
Iridium is "really a cellular system turned upside-down," says Durrell W. Hillis, corporate vice president and general manager for satellite communications at Motorola. "Each satellite projects a set of cells onto the Earth. The Earth-based users seem to be stationary, while the cells move rapidly through space."

In the Iridium system (see drawing), a caller would transmit both his phone number and serial number from a handset (1) to a "smart" satellite (2) capable of relaying the call to another satellite (3) orbiting over the caller's service center (4). After the center checks the billing information and authorizes the call, it would beam a reply via the relay satellite to the original satellite, which would send the call to a satellite orbiting over the called party (5). The signal would be beamed to that party's handset (6) or to an Earth station (7) that would send the call through the local phone network.

By the time the Iridium system is ready for operation in 1996, most people in the United States and Canada will have access to land-based cellular service. But the Iridium system, which will provide service in remote areas, will not compete with cellular systems, according to Mitchell. Potential users include international business travelers, disaster relief workers, and passengers aboard planes and ships.

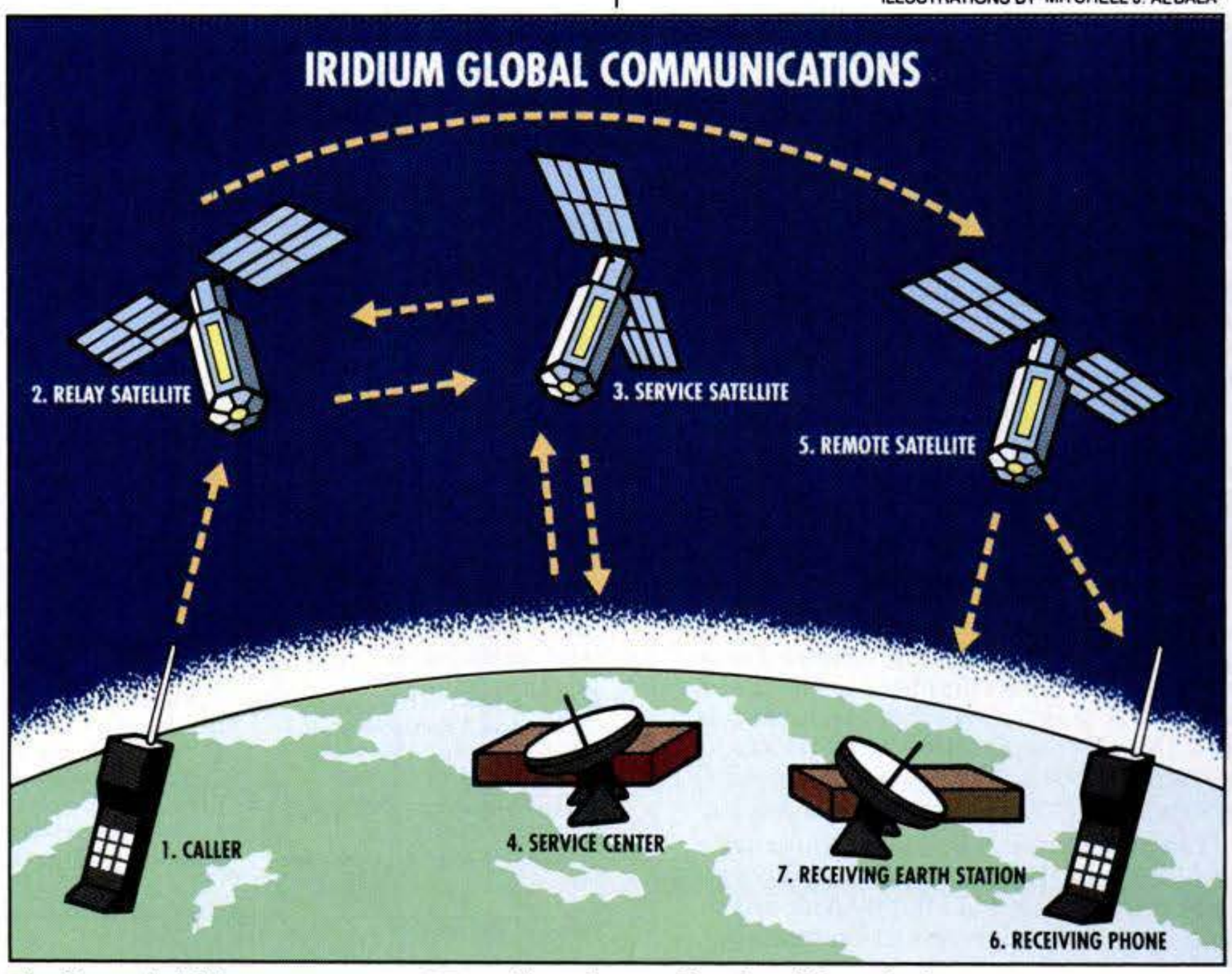
Motorola, which will manufacture the satellites, handsets, and switching equipment for Iridium, is willing to put up 20 percent of the system's estimated $2.3 billion cost, Mitchell says. The company estimates that handsets will be $3,500, and calls will cost $1 to $3 per minute. PS

SELF-INDUCED CIRCUIT REPAIR



An AC current causes depostion on "near-open" circuit paths. Repair time: five minutes.

ILLUSTRATIONS BY MITCHELL J. ALBALA



The Motorola Iridium system uses 77 satellites for worldwide cellular telephone coverage.

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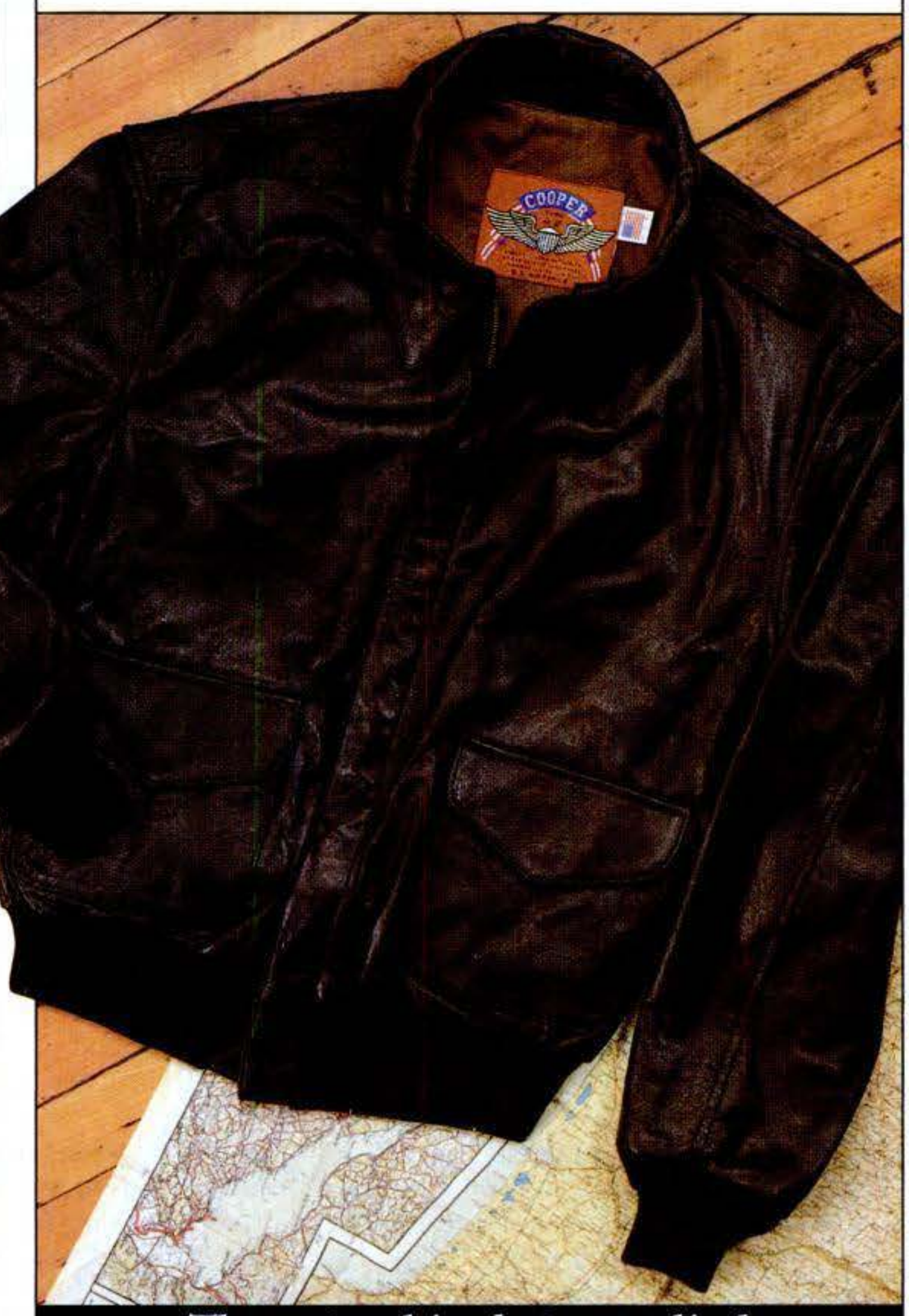

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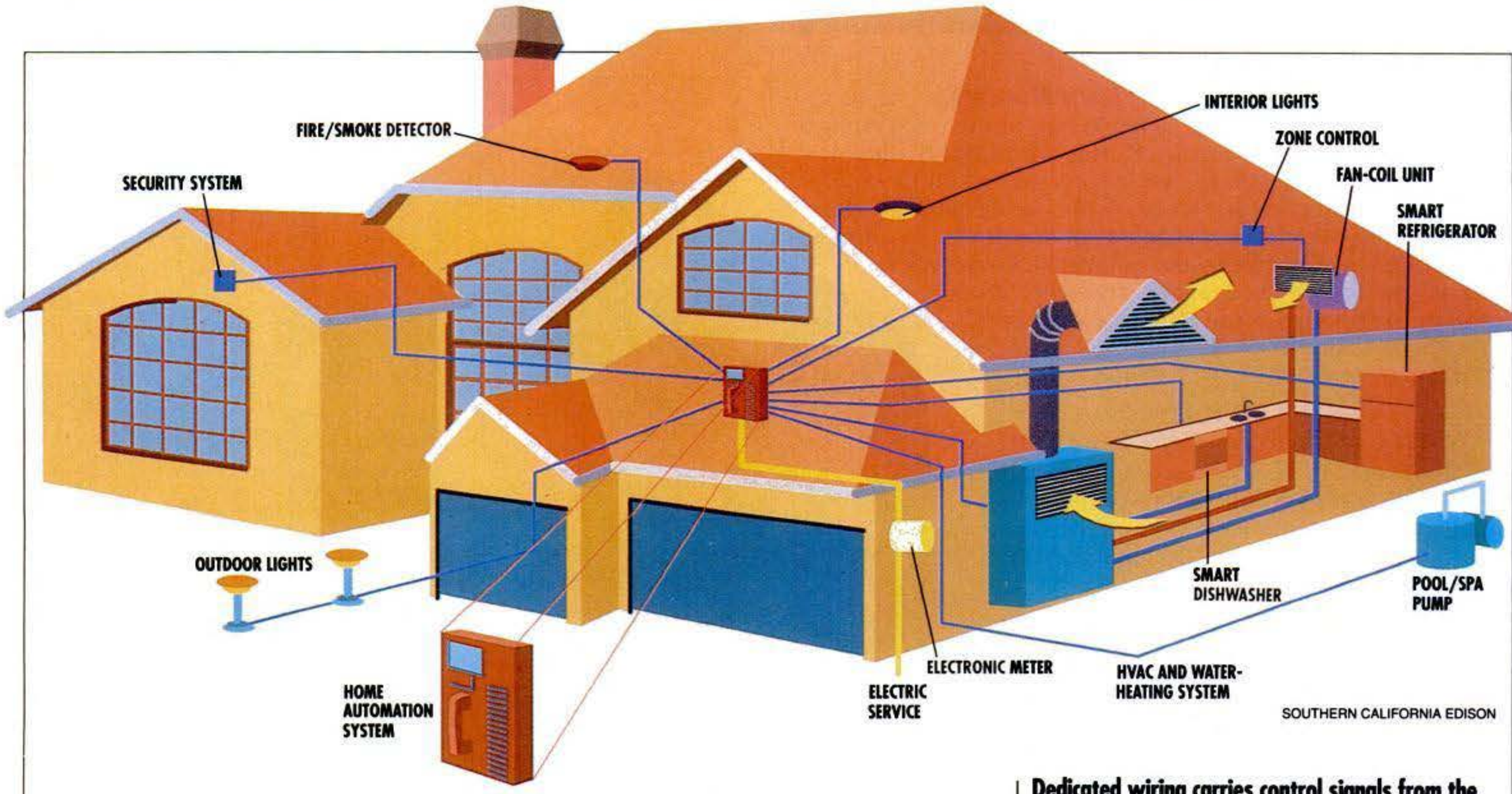
Home Newsfront

By V. ELAINE GILMORE *with Mariette DiChristina, David Peterkofsky, and Judith Anne Yeaple*



Dedicated wiring carries control signals from the central computer to appliances in Southern California Edison's House of the Future.

Open (automated) house

If you read last month's cover story you know that in Tokyo the public can tour an intelligent house that's a feast for the eyes as well as the imagination ["Intelligence With Classic Style"]. And in the Netherlands, about 35 miles south of Amsterdam, a house that's a test bed for home automation and innovative building materials and techniques is a must on every technophile's itinerary ["Bauhaus With Brains"].

But what about here?

Although there is no automated display house in North America with the prowess of these two, there are a couple of houses, one on each coast, where you can meet this aspect of the future. The diagram above shows the automation system of one, Southern California Edison Co.'s 1,000-square-foot "House of the Future" in Irwindale. It serves as a model house for a development that includes 15 occupied houses, automated to varying degrees.

Stylistically, this white frame house would fit in on nearly any block in suburban America, but it resides within a larger building, called the Customer Technology Application Center.

Inside, as well, the house looks pretty conventional—with some subtle exceptions. Just inside the door, for example, is the control panel for the elaborate security system. It includes a minuscule TV screen. From there you can play Big Brother by flipping on TV cameras all over the house; there's one in every room and one at the front door.

Walk into the kitchen and you'll see the central computer for the home-automation system mounted in a wall. Its control panel is a touch-screen CRT. From the main menu you simply touch the relevant word on the screen: To lower the temperature setting, for example, you start by touching "Climate."

Also in the kitchen are some sophisticated appliances, including an electric range from Amana that sports two halogen burners; these glow a ruby red the moment you turn them on ["Cooking With Halogen," May '89]. More to the point, the range and other appliances have been specially modified for control by the central computer, which can see to it that the self-cleaning oven works only at night when electric rates are lowest. Likewise, the refrigerator can be instructed to make ice and the dishwasher to do its work when bargain electric rates are available.

How does the system know when electricity is cheapest? "The information comes through NetComm, a radio link between Edison and its customers," explains Joseph Kelly, senior research scientist at Edison. "Little radio transceivers are placed atop street lights about five miles apart. Edison transmits the current electric rate to the customer's electronic meter via the NetComm radio link." Communication signals between the meter and the home's central computer travel over a dedicated line.

Edison's goal is to even out the load on its generators—shaving the peaks and filling in the valleys—by selling electricity for less when loads are light. Perhaps the major weapon in the load-leveling war shown in Edison's House of the Future is a thermal-storage heat pump: It heats or cools water at night when rates are lowest, then circulates the water through a fan-coil the following day to heat or cool the house.

If you'd like to know the hours and location of Southern California Edison's House of the Future, write to CTA Center, 6090 N. Irwindale Ave., Irwindale, Calif. 91702.

Meanwhile, in the city of brotherly love, an outfit called the Philadelphia Home & Design Centre has built a show house that includes a home-automation system named PAL (for Personally Automated Lifestyles). PAL is a joint project of Square D, Bell Atlantic, and Teletimer, which have announced that the system will conform

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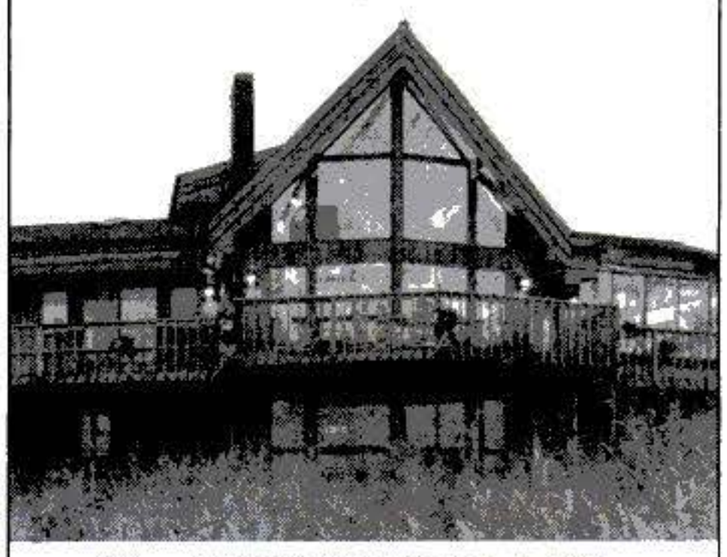

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to the Electronic Industries Association's home-automation standards when they become a fact ["The Integrated, Automated, Educated House," June]. The house, a 3,970-square-foot red-brick mansion, was built by A. P. Orleans, Inc., and is called the Orleans Idea Home.

Like the home-automation system in the California house, the PAL system is built around a central computer that has a touch-screen CRT as its people interface.

Audio tapes in every room explain how the PAL system works, and hostess Marilyn Swartz shows visitors some of the tricks it can do: Open and close the drapes and a skylight, start the fireplace and shut it down, and change the lighting scheme, all according to programmed schedules.

The PAL computer also controls a security system. In the dining room Swartz cautiously opens a window. Instantly a voice blares from a speaker: "There is an intruder in the dining room area." Unperturbed, she goes to the screen, calls up a floor plan of the house, and disarms the system.

From the screen she calls up the image of a thermometer. By moving her finger up and down the scale she can change the temperature setting for a room. In another mode, she calls up recipes from the computer's memory and points out that the items listed in red are out of stock.

Be forewarned though: The overriding idea behind the Orleans Idea Home is to get you to visit the shops in an adjacent mall and buy some of the furniture, housewares, and other goodies you've seen displayed in it. That doesn't include the PAL system yet, however. It is expected to be on the market in late 1991.

A phone call to 215-281-9171 will get you more information. A modest admission to the house is charged.

Clear as crystal

A new copolymer coating does for windows essentially what Teflon does for pans. Made by Ritec International Ltd. of London, the transparent Clear-Shield coating chemically bonds to glass to help keep it free of dirt and reduce surface degradation.

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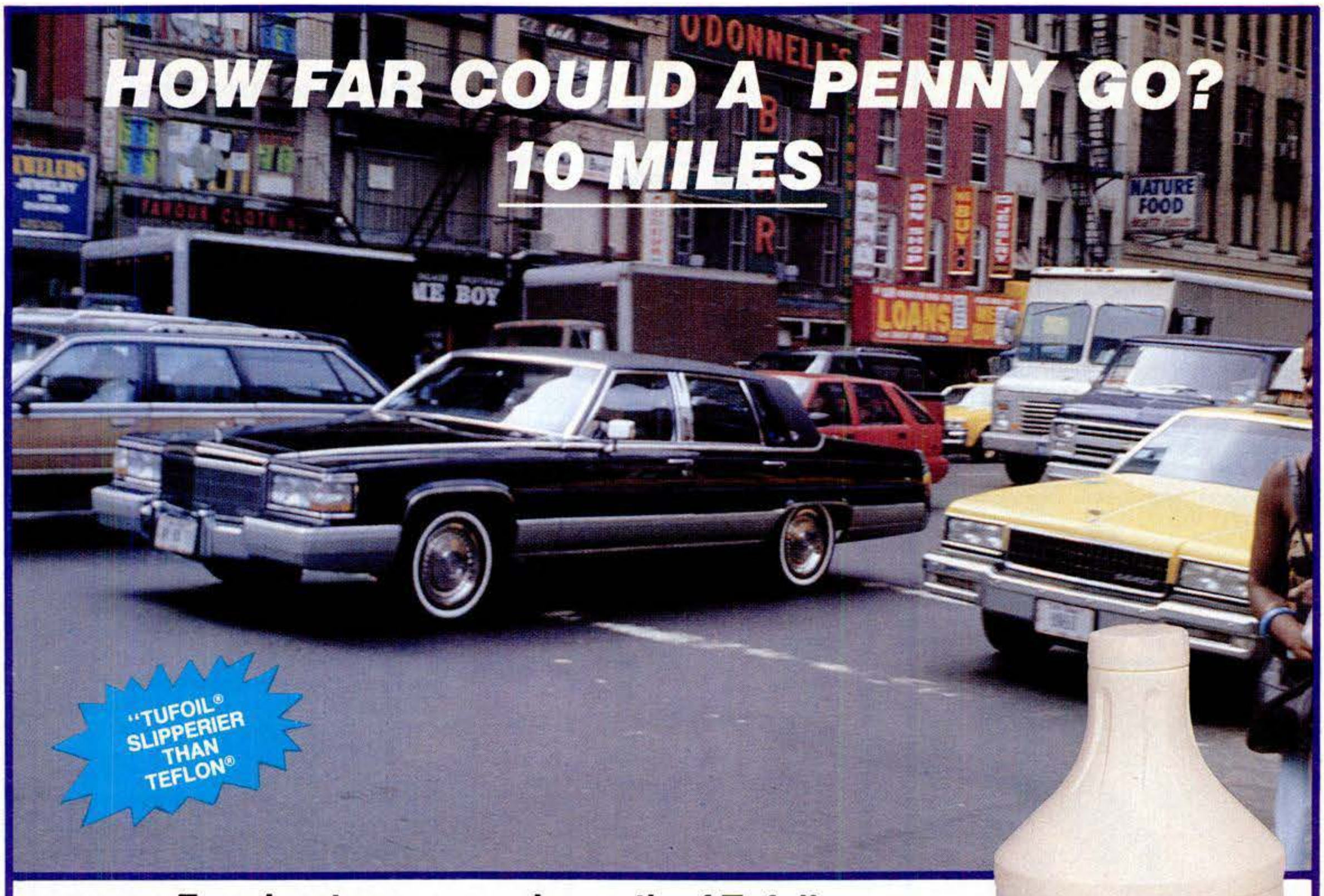

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in 15 minutes to a coating less than one micron thick. But it isn't a job for homeowners: The glass must be chemically clean for the coating to adhere properly. "Windex, water, and ammonia won't do the trick," says Harry Zegers of Zegers Inc., the U.S. distributor. The glass also needs periodic cleaning with solutions made by Ritec.

In Holland, the House of the Future uses Clear-Shield for its expanses of glass ["Bauhaus With Brains," Sept.]. And Prince Charles, that foe of "bad" architecture, bestowed on Ritec the Prince of Wales Award for Industrial Innovation and Production in 1987.

Clear-Shield costs about $2 to $4 (applied) per square foot of existing glass and runs about 50 to 75 cents per square foot for new glass. Residential application services have been opened in Minneapolis and Atlanta. "Within three years, such services will be available nationwide," says Zegers. Zegers Inc., 1700 McCoba Dr., Smyrna, Ga. 30080.

Concrete counter tops

That's right. Concrete. A California architect blends different aggregates with cement to make a concrete for counters that overcomes the drawbacks of the standard mix: weight and workability.

"Aesthetically, Syndecrete is a cross between limestone and honed granite," says David Hertz, who became interested in concrete after a summer construction job. "Unlike synthetic

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It's no secret in the finishing industry that when it comes to hardness, durability, and water-resistance, tung oil has always been the king of oils. So it only seems natural that tung oil would be the cornerstone of all exterior oil finishes.

Surprise! The first penetrating exterior finish based largely on tung oil is Hope's Exterior Tung Oil Finish, and it just appeared on the market last year.

What took so long? According to Hope's John H. Finnegan, there were several problems to solve. Like linseed oil and other penetrating oils, tung oil is susceptible to mildew. Like other unpigmented finishes, it's vulnerable to ultraviolet light when used outdoors. At about $50 a gallon, tung oil also is too expensive to use straight. But diluting it with organic solvents runs into a new problem: environmental regulations that limit the quantity of volatile organic compounds a coating can contain ["Clean-Air Paints," Aug.]. These enter the air when solvents evaporate during and after application.

Hope solved all these problems with a formula that contains UV absorbers, mildewcides, and micronized wax to increase water repellency, and it uses water and ammonia as the solvents. Also, it uses some linseed oil, which is cheaper, to reduce the cost. Total solids content (what's left behind on your wood after the solvents evaporate) is about 25 percent, high for a clear exterior finish.

The result is a penetrating finish that protects wood against weather and UV-caused graying. It won't crack, chip, or peel. It's nonflammable, complies with existing air-pollution regulations, and washes off your brushes and rollers with soap and water.

In my tests, it brushed on easily, darkening the wood and accentuating the grain as you'd expect any oil finish to do.

According to Finnegan, your first two-coat application should last about a year before it needs recoating. After that, you can expect to go two years (maybe less in the South) until you need to recoat to prevent the wood from graying.

The suggested price for Hope's Exterior Tung Oil Finish is $24 per gallon, but discounts to as low as $14 are sometimes available.—*A. J. Hand*

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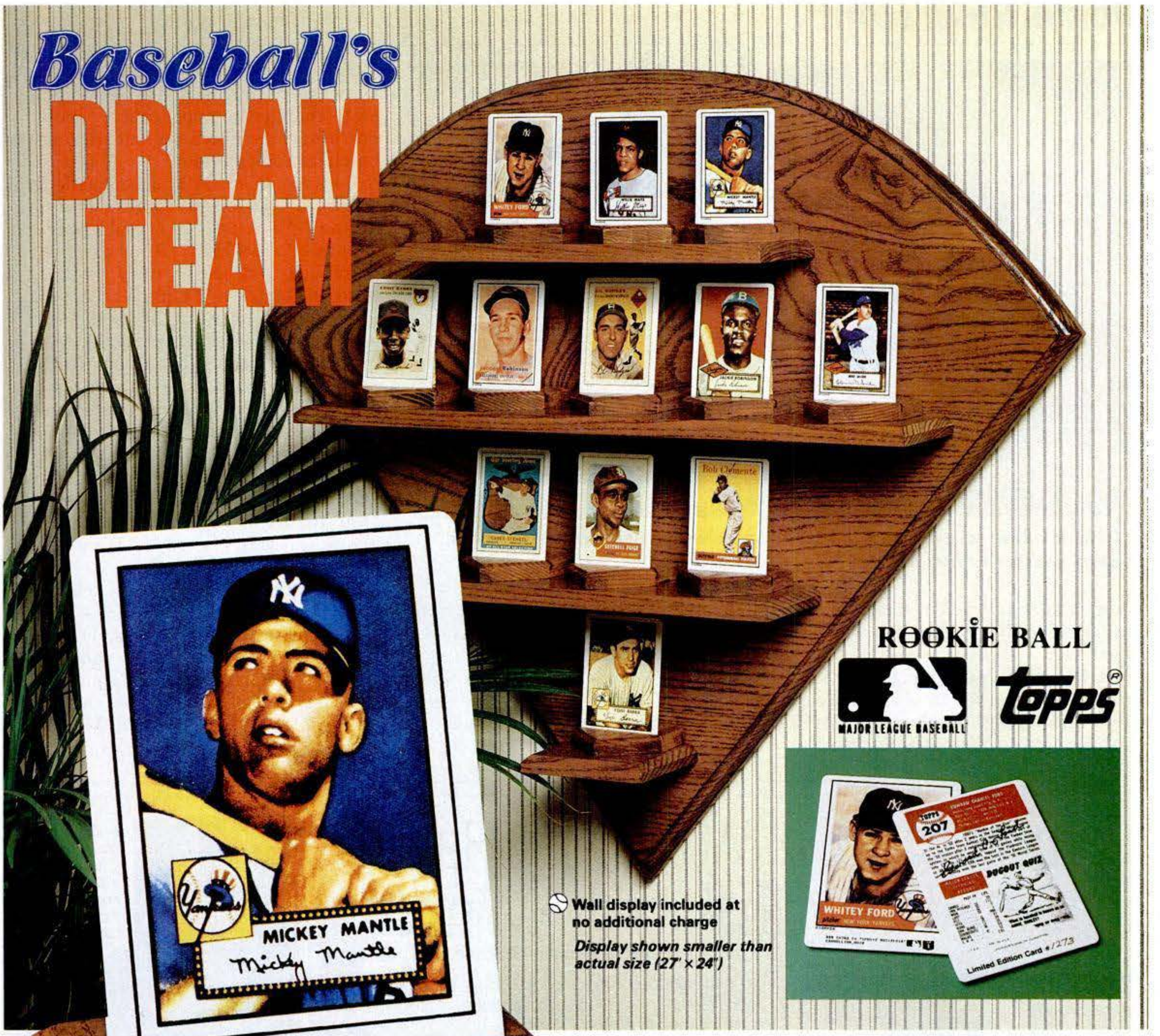
Baseball's DREAM TEAM



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A California architect has invented a new-recipe concrete, which he casts into custom counter tops, showers, floor tiles, furniture, and more. It is available in more than 100 hues.

counter-top materials, it retains a natural quality. Every piece has a unique character."

At 75 pounds per cubic foot, Syndecrete is half the weight of regular concrete and far lighter than granite or marble. "And unlike stone or regular concrete, you can shape or route Syndecrete with standard carbide-tipped woodworking tools," claims Hertz.

Rather than the usual coarse sand or rock aggregate, Syndecrete contains porous volcanic rock, such as pumice, vermiculite, or basalt. In addition, wood or marble chips, brass shavings, or crushed glass can be added to change the appearance. Finally, polypropylene fibers are added to the batch for reinforcement.

Because it is cast and not made in sheets, a Syndecrete counter has no seams. "We pour it like you'd pour a sidewalk," says Hertz. After curing, it is sanded and coated with a water-based sealer. Last, a liquid acrylic wax is applied. "The wax makes the surface resistant to oil penetration, water absorption, and stains from food," says Hertz.

The resulting counter is as rugged as, well, concrete. "You can put a hot pot on it and it won't scorch or melt," says Hertz. But some abuse, like splatters of hot oil, can mar the wax. "You can fix that by sanding and reapplying the wax," he says. "We give a bottle to every customer."

Prices range from $50 to $60 per square foot for installation of a two-inch-thick counter. Tables, chairs, floor and bathroom tiles, showers, sinks, and tubs cast with Syndecrete are also available. Syndesis Studio, 2908 Colorado Ave., Santa Monica, Calif. 90404. PS

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David Clark, *Audio* Magazine, Sept. '89

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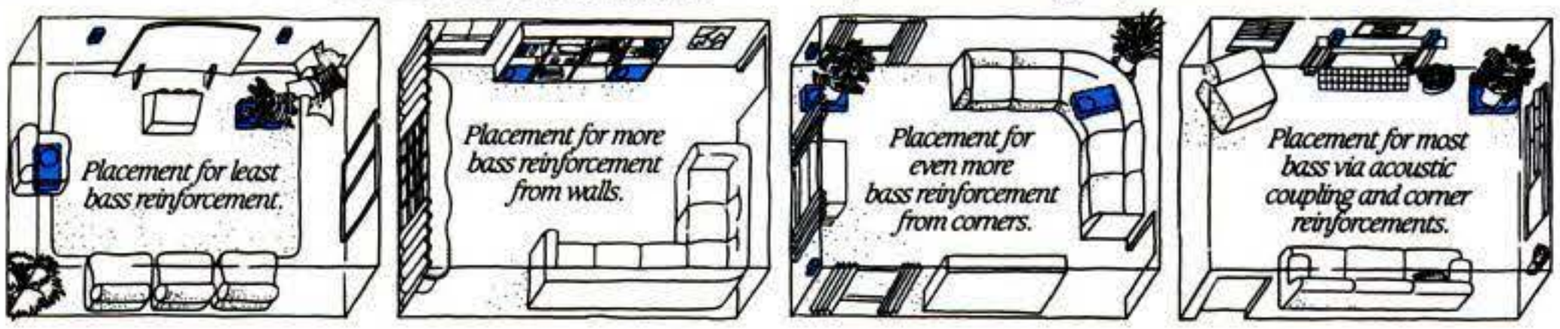
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Radar Warning Breakthrough

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> *BMW Roundel, December 1989*

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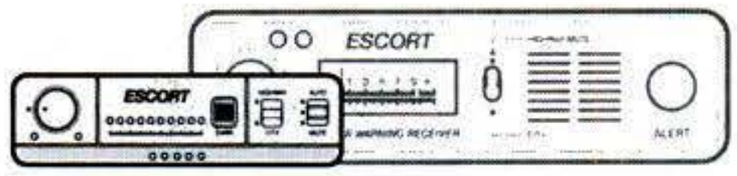

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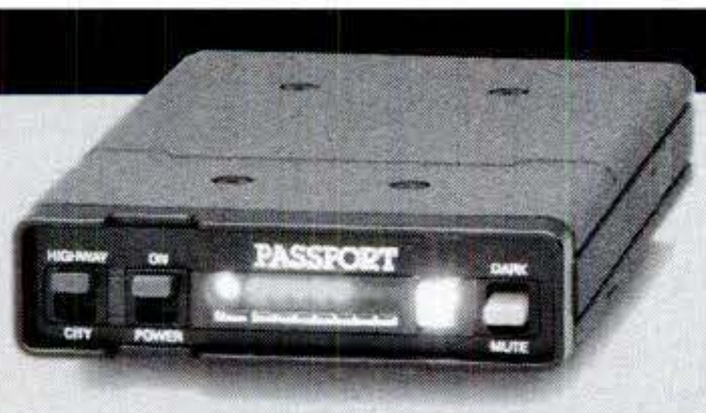

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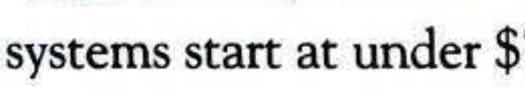

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Popular Science
OCTOBER 1990

With 80 percent of U.S. landfills closing in just 20 years, we're in danger of drowning in our trash. New technologies that degrade, recycle, or burn garbage more efficiently offer a lifeline.

By MARIETTE DiCHRISTINA

"Look at this," yelled a member of the University of Arizona's Garbage Project recently. He had pulled a newspaper from a putrid pile of dirt and debris scooped from the depths of a landfill. It was yellow, but as legible as the day it was printed, Jan. 8, 1952. A headline asked whether Truman would run for president.

Moral: We can't go on just throwing away our garbage, because covering it up doesn't mean it vanishes.

By now, the litany is familiar: While we are generating more and more garbage per person and as a nation, we're running out of legal places to put it.

Each American tosses 4.0 pounds of the stuff daily, or more than half a ton a year. As a nation, it adds up to 179.6 million tons annually—enough to fill a convoy of 10-ton garbage trucks more than 145,000 miles long. By the year 2000, the EPA predicts we will each produce 4.4 pounds daily, for a total of 216 million tons a year.

Part of the problem is that some 73 percent of America's trash is buried in landfills—recycling and incineration account for 13 and 14 percent, respectively. But one-third of existing landfills will close in two years; 80 percent will shut within 20 years. Meanwhile, opposition to new landfills as well as refuse-treatment centers is fierce, driving up costs for the remaining landfills—from nominal charges a few years ago to more than $100 per ton of trash in many areas today.

"Our problem is summarized by the first law of garbage," says William D. Ruckelshaus, former two-time EPA administrator and now chairman of Browning-Ferris Industries of Houston, a waste hauler. "Everyone wants you to pick it up, and nobody wants you to put it down."

But we have the ability to handle garbage more intelligently using both emerging technologies and new and improved versions of older solutions: Garbage can be used as a raw materi-

HOW WE CAN WIN THE WAR AGAINST GARBAGE

LOUIE PSIHOYOS

al for new products. It can be a source of fuel for power plants. It can be better collected and automatically sorted for recycling. And some communities are showing the way toward handling the fetid mass as an asset.

Municipal solid waste is the official name for what most of us call garbage. It includes everything you might throw away at home, from natural materials, such as grass clippings and banana peels, to items containing hazardous substances, such as nail-polish-remover bottles and household batteries. (It is not, however, commercially produced toxic, radioactive, or hospital waste.)

Like the garbage itself, the solution to managing our trash will come from a few sources. Integrated waste management—recycling (including composting), incineration, landfills, and reducing the amount of garbage generated—is the likely answer.

"Traditionally, we have looked at waste as one big mass that gets handled one way," notes David Loveland of the National Recycling Coalition in Washington, D.C. "It's landfilled, or it's incinerated, or now we're talking about recycling it. But we need to manage the individual components of the waste. Many things are appropriate to recycle. Some may be more appropriate to landfill or incinerate."

By 1992, the EPA wants the nation to divert 25 percent of its garbage to recycling—a stiff goal by all accounts. But the idea has tremendous potential for managing waste: In a 10-week experiment, researchers at Queens College in New York City found that 84 percent of household trash was recyclable. Recycling also gives people the kind of righteous satisfaction that makes it a popular option.

One high-tech recycling success story is Rhode Island's. In 1986 it became the first state to mandate recycling, requiring that at least 15 percent of residential and commercial waste be diverted for reuse.

"We get almost ninety percent participation," notes Thomas Wright, executive director of the Rhode Island Solid Waste Management Corp., a quasi-public agency. In comparison, says Wright, bottle-bill states achieve 60 percent compliance. Why? "Convenience," he explains. Instead of lugging recyclables to a reclamation center, residents put glass, "tin" and aluminum cans, and plastic containers in a 12-gallon container (of recycled plastic). Newspapers are stacked on top and are stored in a separate compartment on a collection truck.

All the goods go to a materials-recovery facility, or MRF, in Johnston, R.I. The $5 million facility processes 90 tons of recyclables and 120 tons of newsprint daily. The recyclables are dumped on a conveyor, and machines using technology licensed from Maschinenfabrik Bezner, a German company, do almost all the rest.

First, an electromagnetic belt separates ferrous metals (including "tin" cans, which are steel that is sometimes plated with tin). As the materials continue up an inclined conveyor, glass containers roll down through chain curtains. Glass is sorted manually by color. Aluminum comes out next. An eddy-current magnet induces an alternating charge in the cans, making them hop off the belt. Plastic is sorted manually.

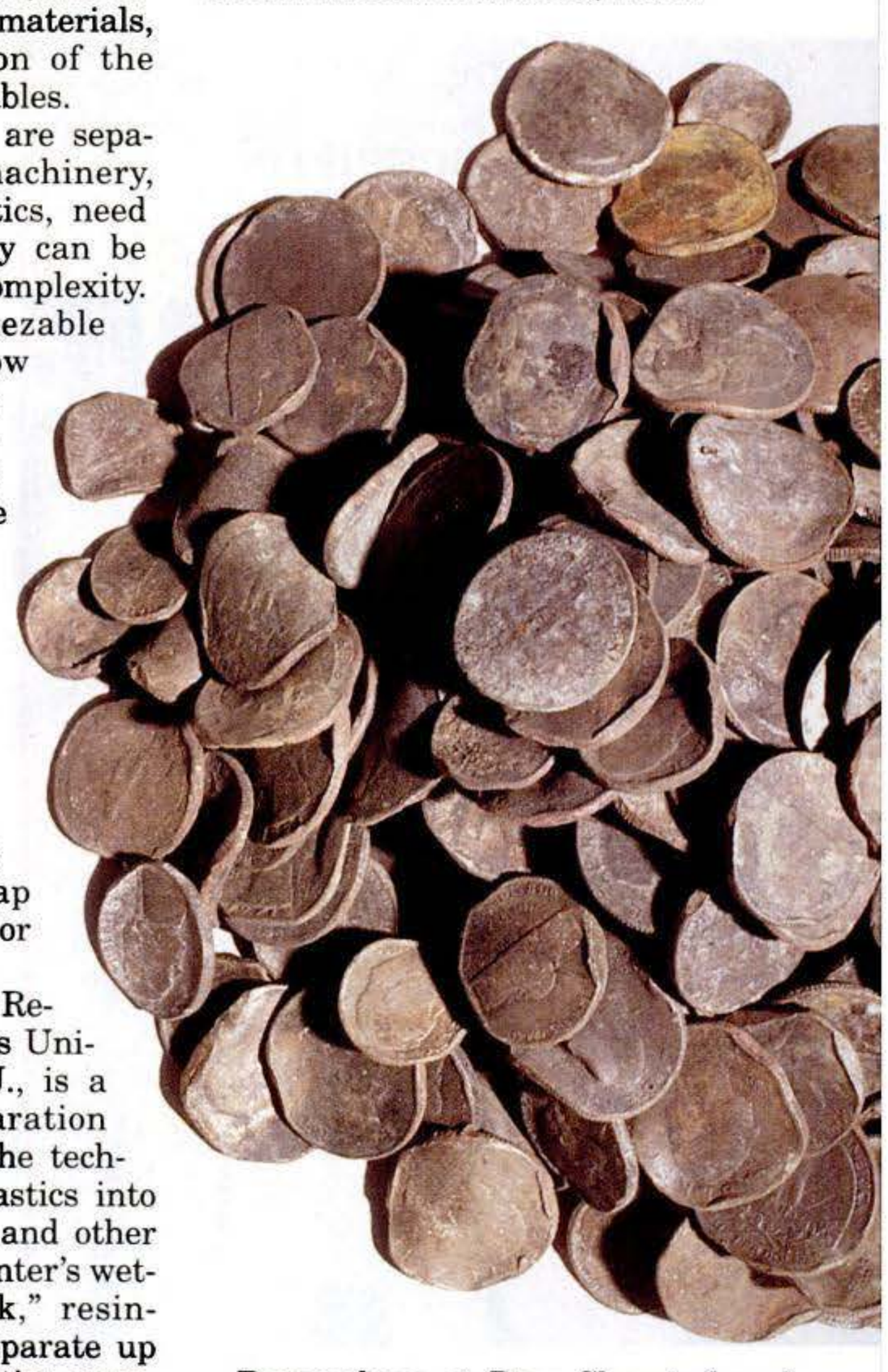
How much does it all cost? Rhode Island officials say $100 a ton, including the price of collecting materials, construction and operation of the MRF, and marketing recyclables.

Whether the recyclables are separated by consumers or machinery, many materials, like plastics, need further sorting before they can be reused because of their complexity. One example is the squeezable Heinz ketchup bottle: Now made of difficult-to-recycle layers of plastic and adhesives, next year it will be sold in a more recyclable form that contains no adhesives. And when you look closely at a plastic soft-drink bottle you find the colored base is high-density polyethylene (HDPE); the clear or green portion is polyethylene terephthalate (PET); and it also has an aluminum cap (with plastic liner), a paper or plastic label, and adhesive.

The Center for Plastics Recycling Research at Rutgers University in Piscataway, N.J., is a leader in developing separation technologies. It advanced the technology to recycle mixed plastics into "lumber" for park benches and other products. In addition, the center's wet-reclamation, or "float/sink," resin-reclamation method will separate up to 50 million pounds of plastics annually in a Bridgeport, N.J., plant built by Day Products.

To reclaim plastics such as PET or HDPE, bottles are shredded, washed, and pumped into a tank of water. There, PET and aluminum settle, while HDPE floats to the top and is skimmed off. A rotating drum uses static electricity to separate PET and aluminum. The resulting plastic flakes are later manufactured into products including containers, soda-bottle bases, pipes, insulating fiberfill for jackets, and yarn for carpets.

Another approach to sorting plastic comes from John Brown Plastics Machinery of Providence, R.I. Baled PET and HDPE bottles are broken apart by a bale breaker and granulated. The plastic flakes are stripped of labels by an air-separation system, washed, and separated by a series of hydrocyclones, vertically oriented cylinders in which pumped-in water spins around the side, like a cyclone. Additives change the water's density so the lighter HDPE spins upward and exits with the flow at top. The heavier PET and aluminum particles drop out. A 1,000-pound-per-hour demonstration test lab is operating at the Cumberland division of John Brown in South Attleboro, Mass.



Researchers at Dow Chemical and Du Pont have developed "compatibilizers," which form chemical links between some types of plastics. This avoids complete separation and enables recyclers to combine resins into a plastic with new applications—a method already used to create new plastics.

While recycled resins are found increasingly in containers, they are not likely to be widely used for food and beverages. Because plastic can absorb

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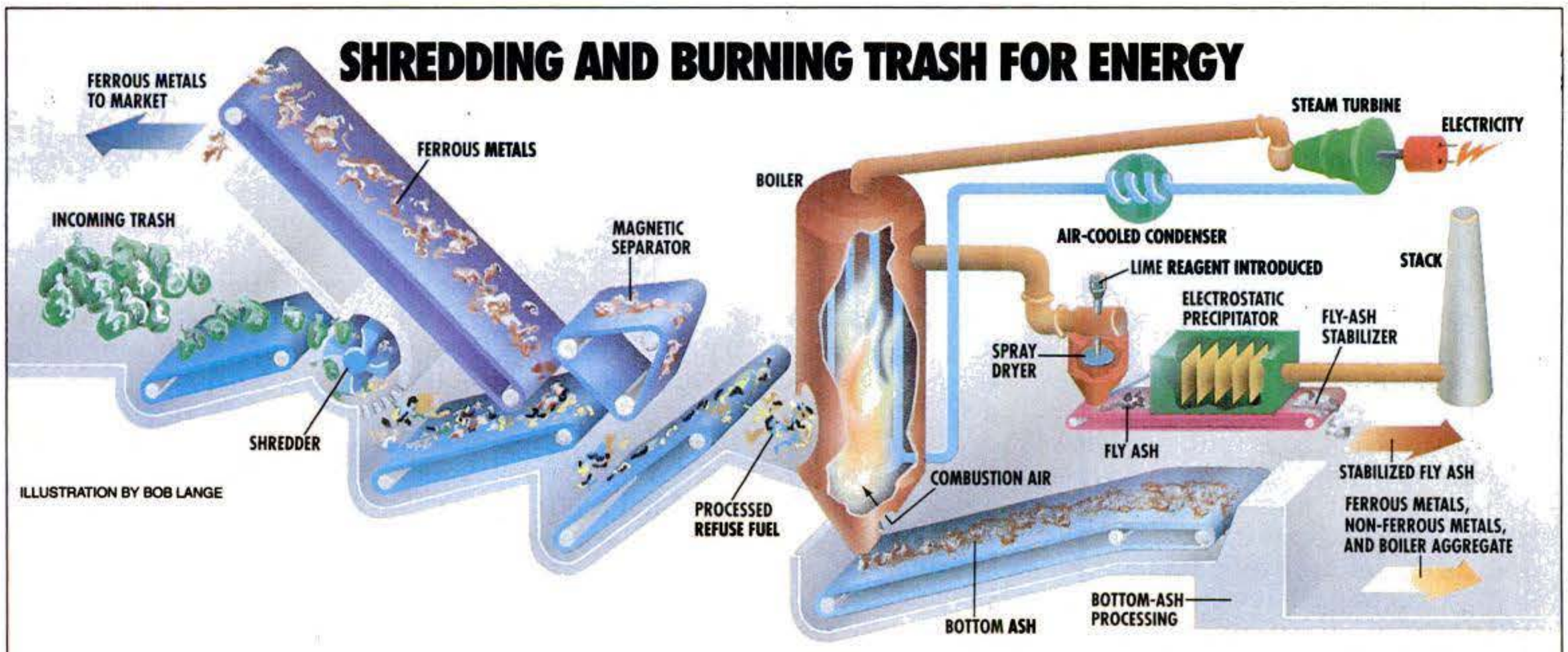

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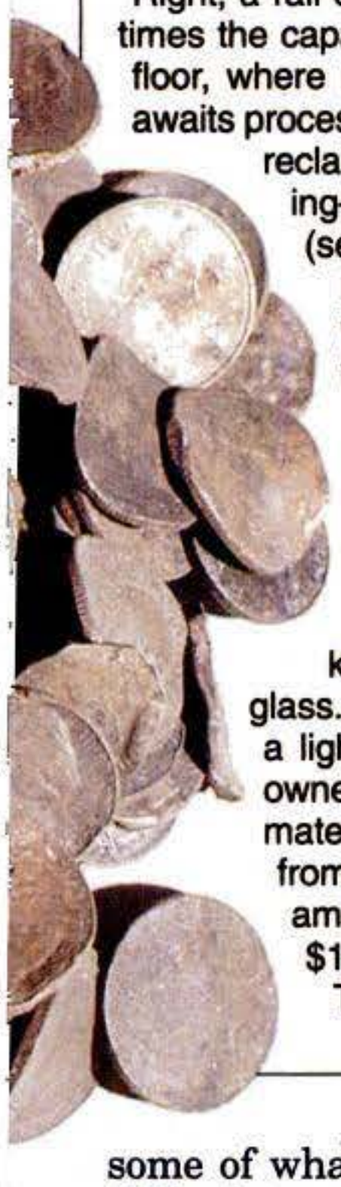

An example of a plant that uses refuse-derived fuel, the Semass Waste-to-Energy Facility in Rochester, Mass., shreds and burns trash from 32 communities, generating more than 50 megawatts. A portion of the electricity is used to run the plant; the rest is sold to a local utility.

Right, a rail car dumps 40 tons of trash—five times the capacity of a truck—onto the tipping floor, where unsorted trash is stored while it awaits processing. Most of the ferrous metal is reclaimed magnetically before burning—the rest is collected afterward (see above illustration). Then hammermill shredders tear up the waste. To improve combustion, the fragments are blown into the boiler, where they ignite midair in temperatures well over 2,000 degrees F. Heavier non-combustible objects, such as glass and remaining metals, fall to the grate, where temperatures are kept below the melting point of glass. These materials become part of a lightweight aggregate, called Boiler Aggregate, that the owners are proposing to sell for uses such as road-building materials. Non-ferrous metal, including aluminum, is sifted from the bottom ash, which comes off the grate. Left, among the metal collected from the bottom ash for scrap: $1,500 in coins daily.

To treat flue exhaust, each of the two boilers has an acid-gas scrubber and an electrostatic precipitator with five fields, areas where charged fly-ash particles collect on oppositely charged plates, like paper on a comb.

To aid local recycling, plant owners are experimenting with having homeowners place recyclables in bright yellow bags, which are easily pulled from the tipping floor. The materials are sold to processors and end users of recyclable materials.—*M. D.*

some of what it contains, it has been difficult to guarantee purity. One exception: Dolco Packaging Corp. of Sherman Oaks, Calif., has government approval to use recycled polystyrene in egg cartons.

Composting, which reuses plant matter, is often considered a form of recycling. With the action of microbes, fungi, insects, and worms, it can transform vegetative matter into a dark, rich soil. And it doesn't have to be unpleasant on a large scale: "A properly run composting facility can generate good odors—the smells people associate with a forest on a wet day," says Tom Richard, a senior research specialist in the Cornell University Department of Agricultural and Biological Engineering.

The Ithaca, N.Y., college helped run a pilot 500-ton-per-year yard-waste composting project in Westchester County, N.Y. The waste was arranged in long piles called windrows and periodically turned to maintain temperature, moisture, and oxygen levels.

One concern about using yard waste, that the chemicals homeowners use to kill bugs and weeds and encourage grass growth could make the compost undesirable, didn't happen. "As far as pesticides are concerned, you could eat this compost," says Richard, who attributes this to lawn products that quickly degrade. Richard put the per-ton cost of composting at this facility at $15 to $20. Composting is being conducted now in many areas of the country.

Anaerobic microbes, which live in oxygen-free environments, also could compost waste while simultaneously generating methane gas, a fuel source. The Illinois Biomass Energy Program in Du Page experienced good results with sewage sludge in a one-year test using sequential anaerobic fermentation, a method where several degradation steps are mediated by separate groups of anaerobic bacteria. The bacteria convert organic wastes to methane and a solid residue for medium-grade ammonia-containing fertilizer. A second study is planned for yard wastes.

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Sam Ghosh, a professor of civil engineering at the University of Utah, who developed the technique, says similar processes can produce other useful materials. "We can convert organic garbage into high-value fuels, such as methane or ethanol, or other chemicals," he says. Ghosh says some 80 percent of what goes into landfills is organic material.

One drawback to recycling has been that after you separate materials, you have no guarantee that there will be a market for them. After a newsprint glut in the Northeast, communities that had been selling their wastepaper had to pay to have it taken away.

"To make recycling successful," says Loveland of the National Recycling Coalition, "we'll need both increased collection and consumer demand for recycled materials."

Some experts say that the rate of recycling cannot be reliably increased enough to make it our sole waste-management solution; incineration, they contend, has to be part of the answer. "Some people argue that we can recycle our way out of our problem," says Richard Magee, executive director of the Hazardous Substance Management Research Center at the New Jersey Institute of Technology in Newark. "I think that's a fairy tale."

Today there are more than 160 household-trash incinerators in the United States. In the spring of 1989 about 45 new combustion facilities were under construction and others were proposed. If all are built, the Congressional Office of Technology Assessment predicts they would increase the combustion portion of the waste-management scheme to 25 percent by the end of the century.

Combustion, under optimal conditions, can cut garbage 90 percent by volume and 75 percent by weight. Emissions are also cleaner in new facilities as a result of the 1987 EPA requirement for the plants to use "best available control technologies." Modern incinerators combine better combustion and emission-control devices, including: "scrubbers," towers that remove acidic vapors in flue gases; electrostatic precipitators, which give fly ash a positive charge and collect it on negatively charged plates; and bag houses, which sift out particles.

As a result, plants built today are a vast improvement over designs from several years ago, says Magee. "We've seen an over-1,000-fold reduction in modern plants in things like dioxin and furan emissions compared with plants built in the 1970s," says Magee. Dioxins and furans are two classes of chlorinated organic compounds that can be highly toxic. "With today's technology, health risks from incineration are small," says Magee.

However, critics contend that waste combustion hinders recycling; may still pollute the air; and produces ash —especially in the case of fly ash— that contains high concentrations of heavy metals, such as lead, mercury, and cadmium, and in some cases dioxins and furans. (Fly ash is particles collected from flue gases.)

"Incinerators do not dispose of waste," says Richard Denison, a scientist with the Environmental Defense Fund in Washington, D.C. "They are waste processors that create wastes that must themselves be managed." Ash is placed in monofills, sanitary landfills for one type of waste, or mixed with household waste in a landfill.

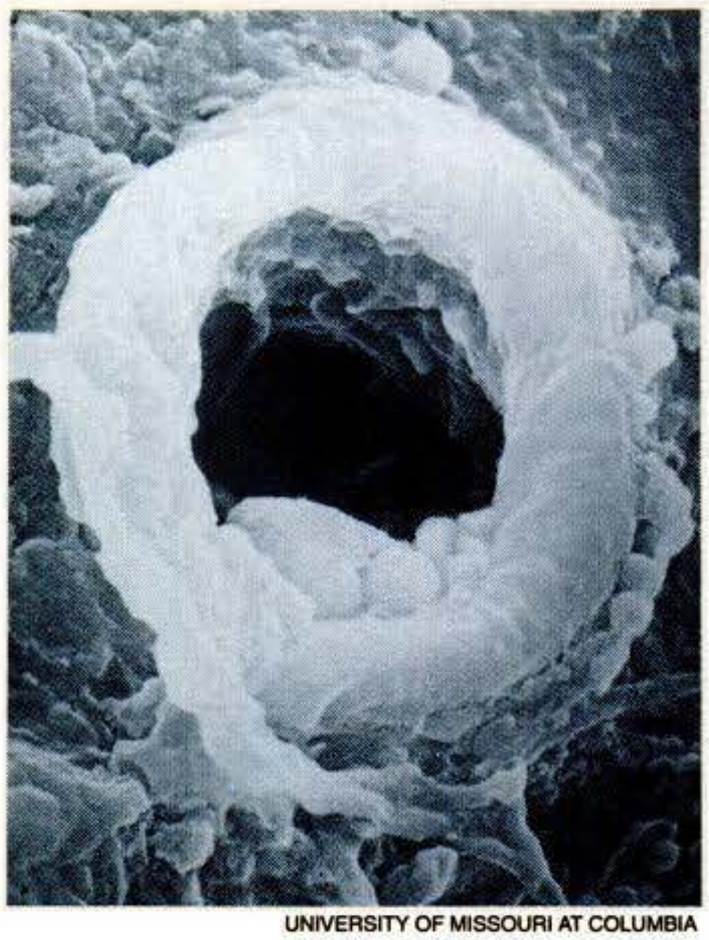
The majority of waste-combustion plants operating today are of the type called mass-burn. The next most common use refuse-derived fuel. Many generate electricity. Called waste-to-energy plants, they use the heat from burning to boil water. The resulting steam can be sold to industry or drive a turbine to generate electricity.

Mass-burn systems burn mixed garbage in one combustion chamber using excess air. In new facilities, garbage fed into the furnace from an

PERISHABLE PLASTICS

The latest salvo in the rush to mass-produce a truly biodegradable plastic was launched recently when ICI Biological Products, a division of the British chemical giant, announced that its plastic would be used in shampoo bottles next year.

Plastic, estimated to be just eight percent of the total waste stream by weight, is nonetheless a very visible symbol of the garbage crisis because it is known to last for many decades, and perhaps centuries, before it degrades.



UNIVERSITY OF MISSOURI AT COLUMBIA

ICI's plastic will be used in shampoo bottles sold by Wella in West Germany. The plastic, called polyhydroxybutyrate-valerate, is produced by a naturally occurring bacteria. The bacteria convert glucose to PHBV, which they store much as humans store fat. The material can be degraded in aerobic conditions to water, carbon dioxide, and humus by naturally occurring bacteria and fungi. However, the company says that in applications like bottles, films, and fibers, PHBV has durability, stability, and water resistance comparable to conventional thermoplastics. Other laboratories are developing similarly made degradable plastics.

Another recent entry is a plastic developed by Warner-Lambert Co. made of starch from potatoes, rice, or wheat. The Morris Plains, N.J., pharmaceuticals company applies pressure, moisture, and heat to form the starch into a malleable substance that can be molded and extruded like other plastics. The company doesn't know, however, when it will produce products made with the plastic. Argonne National Laboratory also has a not-yet-commercial biodegradable plastic, made by fermenting the glucose in potato or cheese whey to lactic acid with bacteria, and then using the lactic acid to construct the plastic.

These plastics are different from the cornstarch-containing variety that has received so much attention from the media.

One type is composed of conventional polymers with up to 15 percent cornstarch. Bacteria eat the cornstarch, leaving the plastic, as in the scanning-electron-microscope photo.

Then the plastic breaks apart into tiny pieces, which most agree will resist degradation for many years. But Archer Daniels Midland Co., in Decatur, Ill., which makes a cornstarch additive for degradable plastic bags that includes an oxidative degradation catalyst, claims tests show the bags will break down in a landfill. The oxidative mechanism breaks down the long polymer chains into small segments, says George Poppe, manager, degradable plastics research, at ADM.

"Degradation is not as fast as in ideal compost conditions," he adds. "But in two to three years biodegradable plastic will lose the properties of the original product."

Photodegradable plastics, another type, generally incorporate chemicals that break down the long polymer chains into smaller segments in the presence of ultraviolet light. Still other plastics degrade with the addition of certain chemicals and water.

But can degradable plastics help solve the garbage mess? The EPA doesn't think so: In a report to Congress in February, the agency said degradable plastic provides little, if any, environmental benefits. And the Council for Solid Waste Solutions, a plastics-industry coalition, instead favors recycling.—*M. D.*

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NO LONGER THE TOWN DUMP

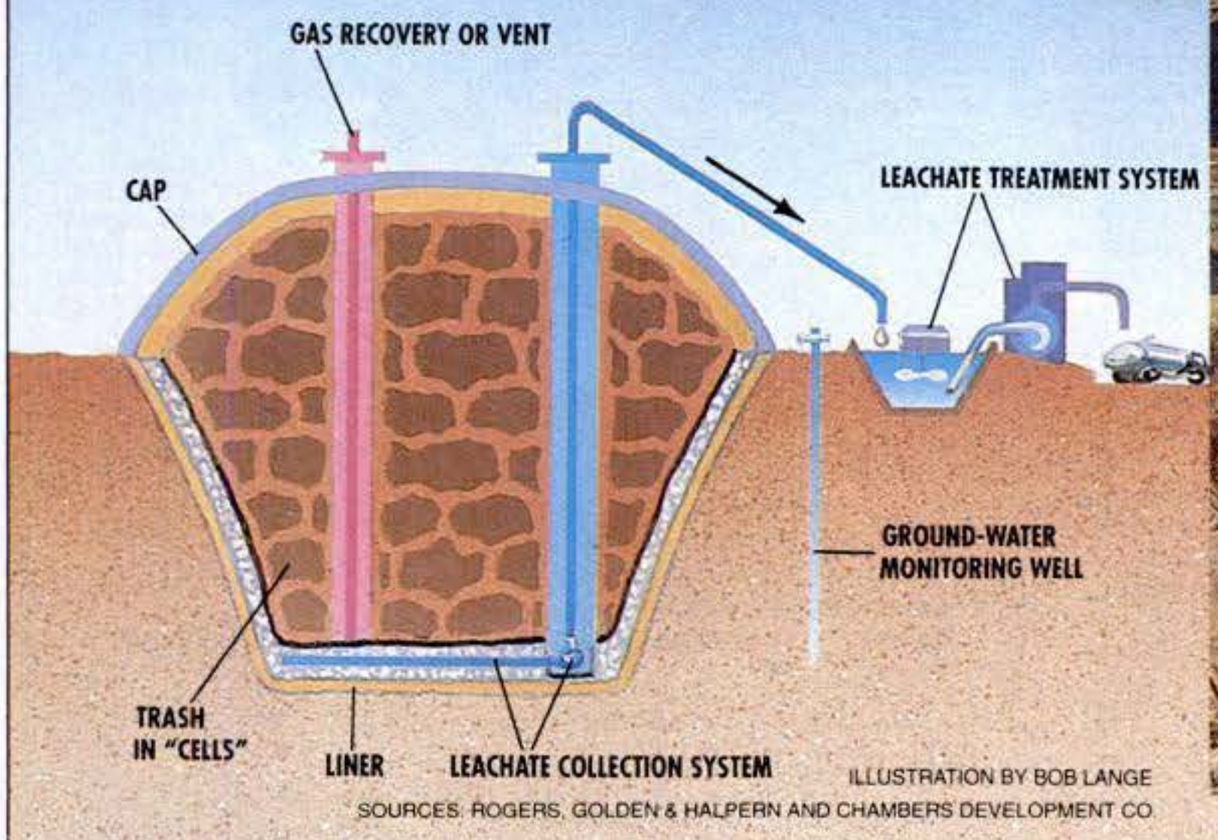


ILLUSTRATION BY BOB LANGE

SOURCES: ROGERS, GOLDEN & HALPERN AND CHAMBERS DEVELOPMENT CO.

PHOTO BY CHAMBERS DEVELOPMENT CO.

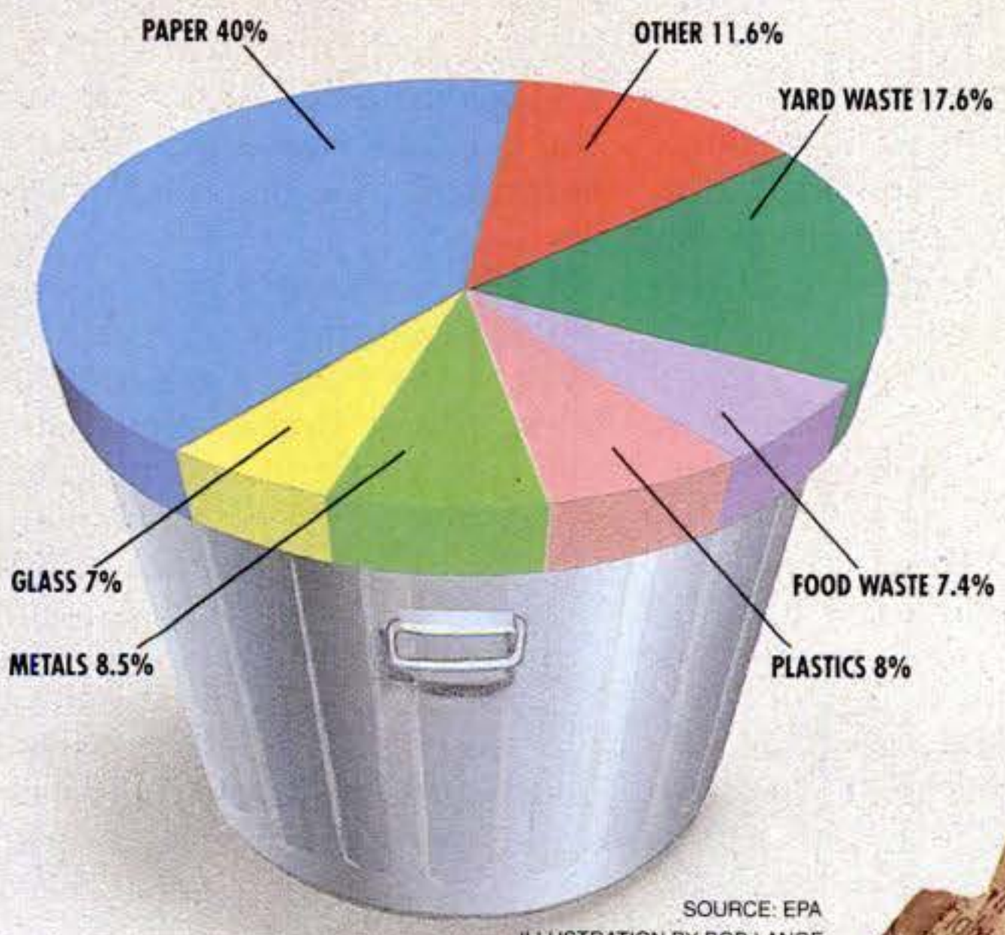
Modern landfills provide many safeguards against environmental hazards, such as contaminating leaks to ground water and methane-gas migration (above left). First, the landfills are sited in more suitable hydrogeologic areas, preferably where ground water is deep and not used as a drinking-water supply. A state-of-the-art sanitary landfill has a liner system comprised of (from top to bottom): a leachate-collection system, a synthetic liner over a clay liner (called a composite liner), followed by another leachate-collection system, and another composite liner. Ground water is also monitored on a regular basis.

Trash is dumped into a "cell," an active part of a landfill that is covered daily with soil to prevent erosion and water infiltration. Because the soil occupies as much as 20 percent of a landfill's space, manufacturers have developed foam products as alternative daily covers. Textiles and plastic tarps have also been used as daily covers. When the landfill is full, the final cover includes compacted clay and a synthetic cap, gas-collection or venting systems, plus a drainage system to prevent rainwater infiltration. Above right, the initial synthetic liner is installed atop a clay liner in this planned eight-acre portion of a landfill in Charles City County, Va. The air-supported structure visible protects against inclement weather during construction. The developer and operator is Chambers Development Co. of Pittsburgh.

Because of the lack of air and water, garbage in landfills is often remarkably well-preserved. "Degradation, next to Santa Claus, is our most popular myth," says William Rathje, co-director of The Garbage Project. "It works in a compost pile in aerobic conditions because the bugs [microbes] there could degrade anything. Below eight to ten feet, you get anaerobic conditions. The bugs there are like the ninety-pound weaklings at the beach—they got a lot of trouble." Rathje says three anaerobic microbes must work in a certain order to degrade paper, for example, and they all like different conditions.

That doesn't mean nothing is happening. "In the first ten to fifteen years of burial," says Rathje, "about one-quarter of the food debris and yard waste biodegrades, producing methane gas." To extend the life of landfills, Argonne National Laboratory in Argonne, Ill., has experimented with adding water to landfill material. The result: Degradation speed triples and the waste generates more methane, an energy source. Rathje isn't sure this is a good idea. "The bugs may be ninety-pound weaklings, but they're not stupid," he says. "They don't eat lead or cadmium or mercury or the acute hazardous material in inks or paints or stains. If you degrade garbage, you may get a concentrated hazardous goo that could leak into ground water." Another point: "People put things on top of landfills—golf courses, parking garages, storage sheds. When you do that, the last thing you want is for the landfill to slump, settle, or subside. And that's what increased biodegradation would do."—*M. D.*

WHAT WE THROW OUT



SOURCE: EPA

ILLUSTRATION BY BOB LANGE

Above, materials in household trash by weight. Figures are for 1988, the latest available. The newspaper at right was unearthed by The Garbage Project of the University of Arizona, which also has found undecomposed foods like hot dogs, carrots, and corn cobs complete with husk.

PERCENTAGES DO NOT ADD UP TO 100 BECAUSE OF ROUNDING

Join Your CHAMBER of COMMERCE
Tempe Daily News
TEMPE TO GET NEW POST OFFICE
Hint Dropped By Truman Suggests He May Not Be Candidate For President
Buffaloes Play Dust Devils Wednesday; Two Teams Tied
Sought By Record 182 Persons

PHOTO BY JOHN B. CARNETT

A SAMPLING OF HOUSEHOLD RECYCLABLES

PRODUCTS	PRIMARY MATERIALS	WHAT HAPPENS	PRODUCTS MADE FROM RECYCLED MATERIALS	FUTURE RECYCLING PROSPECTS
NEWSPAPER	NEWSPRINT	PAPER IS MIXED WITH WATER IN A HYDROPULPER. IT MAY BE DE-INKED WITH DETERGENTS. THE PULP IS THEN POURED OVER A SCREEN THAT RETAINS THE FIBERS, BUT ALLOWS THE LIQUID TO PASS, AND IS REFORMED INTO A SHEET.	NEWSPRINT, CARDBOARD, EGG CARTONS, BUILDING MATERIALS (TAR PAPER FOR ROOFS, INSULATION BOARD, DRYWALL, CREAM SHEET)	VERY GOOD TO EXCELLENT
MAGAZINES AND CATALOGS	CLAY-COATED PAPER	REPULPED, LIKE NEWSPRINT. THE CLAY IS REMOVED ALONG WITH WASTE WATER.	BUILDING MATERIALS	SO-SO. DEMAND ISN'T INCREASING NOW BECAUSE OF NEED TO REMOVE CLAY AND ADHESIVES (IN GLUE LABEL), BUT NEW TECHNOLOGIES MAY ENABLE CONVERSION OF CLAY-COATED PAPER TO NEWSPRINT.
TELEPHONE BOOKS	MIXED PAPERS, ADHESIVE	REPULPED, MAY BE BLEACHED TO REMOVE DYES IN MULTICOLORED PAPER. SCREENS, CENTRIFUGAL CLEANERS, AND ADDITIVES THAT HELP AGGLOMERATION MAY BE USED TO REMOVE ADHESIVE.	BUILDING MATERIALS	SO-SO. EXPORT DEMAND COULD INCREASE. RESEARCH MAY FIND NEW U.S. USES.
FOOD JARS, BEVERAGE BOTTLES	GLASS	GLASS IS SEPARATED BY COLOR, MELTED (WITH RAW MATERIALS OF SAND, SODA ASH, AND LIMESTONE), AND REMOLDED.	GLASS CONTAINERS FOR FOOD AND BEVERAGES	VERY GOOD TO EXCELLENT
BEVERAGE CONTAINERS	POLYETHYLENE TEREPHTHALATE (PET) PLASTIC	SEPARATED BY COLOR, SHREDDED, WASHED. FLAKES ARE SEPARATED FROM METAL CONTAMINENTS (FROM CAPS OR RINGS) AND LATER REMOLDED.	SCOURING PADS, NON-FOOD CONTAINERS, INSULATION, TEXTILES, FIBERFILL, INDUSTRIAL PAINTS, CARPET YARN	VERY GOOD TO EXCELLENT
MILK CONTAINERS	HIGH-DENSITY POLYETHYLENE (HDPE) PLASTIC	SAME AS PET	NON-FOOD CONTAINERS, PAILS, TOYS, PIPES, CRATES, PLASTIC "LUMBER", BASE CUPS FOR PET BOTTLES	GOOD
HAMBURGER "CLAMSHELLS," HOT-DRINK CUPS, PLATES	POLYSTYRENE PLASTIC FOAM	SAME AS PET	OFFICE EQUIPMENT, VIDEOTAPE CASINGS, FLOWER POTS, TOYS, INSULATION, COMBS, GARBAGE CANS	SO-SO TO GOOD. COLLECTION MUST BE INCREASED.
OTHER CONTAINERS, AUTO PARTS	MIXED PLASTICS	ESSENTIALLY SAME AS PET, THOUGH ADDITIONAL SEPARATION IS NOT REQUIRED	PLASTIC "LUMBER" FOR DOCKS AND PIERS, TRAFFIC BARRIERS, CURB STOPS, FENCING, PARK BENCHES, PLAYGROUND EQUIPMENT	GOOD
BEVERAGE CANS	ALUMINUM	MELTED (COATINGS BURNED OFF AT THIS POINT) AND RECAST	BEVERAGE CANS, KITCHEN COOKWARE, LAWN CHAIRS, SIDING	EXCELLENT. ALUMINUM IS A HIGH-VALUE METAL.
"TIN" CANS FOR FOOD AND BEVERAGES	STEEL	MELTED AND RECAST. CANS CAN BE USED AS IS, OR WITH TIN COATING REMOVED.	FOOD AND BEVERAGE CANS, CONSTRUCTION MATERIALS, TOOLS, AUTOMOBILE MATERIALS	VERY GOOD TO EXCELLENT

COLLECTION PROGRAMS VARY: CONTACT YOUR COMMUNITY LEADERS FOR INFORMATION ON RECYCLING IN YOUR AREA.

ILLUSTRATION BY BOB LANGE

overhead crane falls on moving grates that tumble it for better combustion. Combustion above the grates is typically around 1,800 degrees F.

Refuse-derived fuel, or RDF, is made from processed garbage. Metals or glass can be removed, and the remainder can be shredded, powderized, or compressed into pellets or bricks. RDF can be the sole fuel or combined with conventional fossil fuels. Because of processing complexity, RDF has been more costly and less reliable than mass-burn, says the OTA, though many systems have run well after solving start-up flaws.

One such plant is the Semass Waste-to-Energy Facility in Rochester, Mass. Set amidst scenic cranberry bogs at the gateway to Cape Cod, the plant shreds and burns 1,900 tons of trash daily for $20 a ton. It recently received approval for an expansion that will enable it to handle 900 additional tons a day.

Semass daily reclaims 36 tons of metals and generates more than 50 megawatts of electricity. It creates 227 tons of bottom ash, which it proposes for use as a lightweight aggregate for building materials, and chemically stabilizes 126 tons of fly ash so it won't leach toxins, Semass claims. (Bottom ash is the the material that remains on the grate after burning.) And the plant's emissions are laudably lower than environmental requirements demand (see box, page 59).

Semass officials also are testing nonstructural uses, such as lawn ornaments, for the fly ash. "Our goal is zero landfilling," says Gordon Sutin, a vice president at Energy Answers Corp., one of the owners of Semass. Like anything new, however, Semass has had setbacks. One unanticipated summertime problem: the smell.

"We required pollution controls beyond anything that had been done with shred-and-burn technology. But Semass hasn't gotten recognition for that because at times odors from the plant have been extremely strong," says John Winkler, review engineer for air quality at the Massachusetts Department of Environmental Protection. To suppress the stench, the facility has built an air-dispersion tower. When Semass adds a third boiler, the plant will incorporate a mechanism to draw out and burn the odor-laden air, eliminating the problem.

Neutralysis Industries Ltd. of Australia has another RDF idea that combines waste management with making lightweight aggregate. After running a pilot plant in Brisbane, the company plans to construct a plant in Bay County, Mich., to handle 700 tons of trash a day.

After recyclables and metals are removed, the waste is shredded, combined with clay and liquid, and extruded as homogeneous pellets that look like dry dog kibble. "That liquid can be water, sewage, or even some hazardous waste," says Jack Robison, president of Neutralysis. The pellets are subjected to a three-stage rotary-kiln system at varying oxygen levels and progressively higher temperatures. Volatile gases thrown off by the pellets are recirculated to feed the burn. Robison claims the process generates 8 to 10 megawatts of electricity and leaves one-half of one percent of the original waste weight as fly ash because of thorough combustion.

Many others are also experimenting with reusing ash: At the State University of New York, Stony Brook, researchers mix ash with portland cement to make cement blocks for construction. Initial studies indicate that the process prevents toxic metals from escaping into the environment.

Other less-often employed incineration systems also offer promise. Like mass-burn, modular systems can take unprocessed waste. But they are generally smaller and use two combustion chambers. The primary chamber operates in an oxygen-starved environment; here the wastes are vaporized, and the resulting gases are burned in the second chamber, which uses excess air.

Fluidized-bed combustion burns fuel in a liquid or solid suspension—entrained along with intensely hot particles of sand in an upward flow of

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turbulent air. So far it primarily has been used in this country to burn sewage sludge, industrial waste, and coal. In Europe, it has been used in refuse-derived-fuel plants. Bubbling designs keep material near the bottom of the furnace. Circulating designs allow material to move upward and then return near the bed for further combustion. The extreme turbulence may provide more-consistent combustion than mass-burn or RDF at lower temperatures, says the OTA.

Pyrolysis, another method, is the chemical decomposition of waste by heat in the absence of oxygen, and it generally occurs at 900 to 1,400 degrees F. It produces liquid tar and gas that could be used as fuel in industrial applications including electric-power generation. Total Energy Systems of Ft. Lauderdale, Fla., has run a test plant in Asheville, N.C., and is negotiating with several municipalities for a pyrolysis waste-handling plant. "We can use paper, food, yard waste, tires, and plastics," says William Meenan, a spokesman. "For every hundred tons of garbage, we generate one million cubic feet of gas, 150 barrels of oil, and ten to twenty tons of ash residue." This residue must be managed, but Meenan claims it will pass toxicity standards for residue storage in a landfill.

There always will be garbage that can't be recycled, reduced, or burned. And though past practices have made the public wary of allowing new facilities to be sited, current containment technology has made landfills safer.

"With today's technology, landfills are probably the safest solid-waste-management alternative available," says Steve Menoff of Chambers Development Co. of Pittsburgh, a landfill operator. Still, many agree that even the best-designed modern landfill will eventually leak.

"What is most American about our garbage management is that we can't just manage it. We have to make money on it or do something good with it, like reclaim 'useless' land," says William Rathje, co-director of The Garbage Project. "Then we found—oops—these swamps, streams, and coastlines are the worst places to put your garbage because they can leak right into ground water. As a result, we're unwilling to accept landfills nearby."

New York state is a prime example of this challenge. New York City's Fresh Kills Landfill on Staten Island—the world's largest—was constructed in the 1940s on "useless" wetlands. Today the 2,000-acre 150-foot-high dump accepts three-quarters of the city's trash. And more and more trash is shipped to increasingly resentful states as far away as Oklahoma.

But while some areas aren't suitable for landfills, Rathje says that the notion that we're running out of space is wrong. After New York state commissioned a survey of 42 percent of its domain, for example, it found one percent suitable for landfills—but that was still 200 square miles, he says.

If the idea that we're running out of space is one myth, Rathje and other researchers have debunked others. Among their findings: fast-food packaging is just one-tenth of one percent of landfill composition (including polystyrene), and disposable diapers occupy about one percent. The biggest villain? Supposedly degradable paper, which used up 40 to 50 percent of landfill space—newspapers alone were 10 to 18 percent—and was not found to be degrading much at all.

These facts begin to make sense when you learn how a modern "sanitary" landfill is constructed (see box, No Longer the Town Dump). The sites have containment systems to prevent air and ground water contamination—and consequently impede degradation. Menoff says it can cost as much as $1 million an acre for landfill construction and long-term environmental monitoring and maintenance.

The step with the greatest potential for solving the garbage problem—making less trash in the first place—requires cooperation from many groups in ways large and small.

For example, packaging may account for as much as one-third of the volume of what we toss. By designing with a minimum amount of materials, toxins, and metal, companies can help. Reuse, as in the refillable containers that are reappearing for many products, also will cut garbage generation.

But we have to help too, says Maureen O'Rorke, who devised Berkeley, Calif.'s "precycle" public-education campaign. The city encourages purchasing durable products, goods that are recycled and recyclable, and buying in bulk. You can avoid choosing between plastic or paper bags at the store by using canvas or mesh sacks, she suggests.

"To make a significant difference, just quit tossing out yard waste—which is about eighteen percent of

[Continued on page 95]

THE DISPOSABLE-DIAPER DEBATE

Americans use more than 16 billion disposable diapers annually—1.5 million tons a year. Some 85 percent of American babies wear them, and each is said to go through about 8,000 diapers before growing out of the habit. In response to the perceived threat, some 20 states have considered legislation ranging from taxes to bans.

How much of a problem are disposables? William Rathje, co-director of The Garbage Project, found them to be around one percent by weight of the content of landfills he has examined. That's far from the biggest waste contributor (which is paper), but still a large amount for one item.

Some companies are offering solutions with degradable diapers made of polymers with cornstarch (see box, Perishable Plastics). Others contend that these will not help because they take up as much room in landfills as other disposables and will degrade slowly, if at all (see box, No Longer the Town Dump). Maybe the best idea, say many, is to go back to cotton reusables—and in fact the diaper-service industry is experiencing a great renewal of interest. But even here, there are no easy answers.

"If everyone who uses disposable diapers switched to cloth, there would be other environmental impacts: additional water used in laundering, additional sludge that would need treating," notes Norm Crampton of Indiana's Institute on Recycling. "These are unexplored questions."—*M. D.*

TOM WHITE

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There's an all too common notion that owning a 4-wheel drive vehicle means sacrificing a smooth ride and comfortable interior environment. But the 4-wheel drive Ford Aerostar is changing that notion—combining improved traction with ride and handling so exceptional, you may not even realize you're driving a 4-wheel drive vehicle.

Advanced electronic 4-wheel drive and anti-lock brakes.

To help you stay calm (even when the weather doesn't), we gave this Aerostar the most advanced 4-wheel drive available in a minivan: a full-time system that electronically senses road conditions and accordingly adjusts the power given to each set of wheels. In addition, we included standard rear anti-lock brakes, designed to inhibit rear-wheel lockup and help you make straight stops.

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Smooth handling. Comfortable ride.

But since a minivan should be as comfortable as it is comforting, we also gave Aerostar smooth ride and handling, along with a well-appointed, roomy interior. In fact, Aerostar has greater rear cargo capacity than Caravan or Voyager.*

Standard 4.0L V-6 power.

As for Aerostar's 4.0L V-6 engine, it, too, is capable of handling practically anything–like towing up to a 4500-pound trailer.** It's just one more reason Aerostar 4WD is ideal for families on the go. And for families who refuse to let Mother Nature rule the roost.

Ford Aerostar 4WD is *Motor Trend's* award-winning minivan for 1990.

*With rear seats removed.
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It handles the road as easily as it handles Mother Nature.

Buckle up–together we can save lives.

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A three-man crew will soon climb into the spacecraftlike pressurized capsule of a strange double balloon. The boldly engineered craft aims to smash all balloon distance and duration records by circling Earth nonstop.

FIRST EVER EARTH ORBITING

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BALLOON

By STUART F. BROWN

ILLUSTRATION BY JAMES IBUSUKI

One day during a four-month "weather window" beginning this November—when the sky is fair and the wind is calm—a risky balloon launch will begin inside the Loral Airdock in Akron, Ohio, a cavernous 22-story-high blimp hangar as big as seven football fields.

Launch crews will begin pumping 1.4 million cubic feet of helium into an onion-shaped polyethylene balloon that measures almost 170 feet tall when fully charged with the light and pricey gas.

Next the crews will pump ordinary air into a second balloon, this one a perfect 100-foot sphere that looks a lot like a King Kong-sized beach ball. Struts and cables connect the two balloons and provide an attachment point for the sausage-shaped pressurized capsule that houses the crew. Domed polycarbonate portholes in the walls and in the round doors on either end of the 24-foot capsule permit a peek at the three balloonists—an American, an Englishman, and a Russian—settling in amid communications equipment, air-purification paraphernalia, and the various supplies they will need to survive as long as three weeks aloft.

Christened *Earthwinds*, the colossal craft is the most complex manned balloon ever. Its mission is to fly around the world nonstop, a feat that's never been accomplished —even piecemeal—in the 117 years since Jules Verne's fictional account of an 80-day around-the-world balloon jaunt appeared. The crew will use advanced buoyancy-control technology to maintain an average altitude of about seven miles. There, the thin, cold air of the rapid-flowing jet streams will hurry them along.

The adventurers' eastward-drifting journey is projected to last between 12 and 20 days. If the attempt succeeds, it will overwhelm the distance record of 5,209 miles set during the pioneering trans-Pacific flight made by the *Double Eagle V* balloon in 1981, and far surpass the 137-hour duration record set by *Double Eagle II*, the first trans-Atlantic balloon, in 1978.

The crew for this daring venture: Larry Newman, a helium-balloon veteran who was aboard both *Double Eagle V* and *Double Eagle II* during their historic ocean crossings, is captain; Maj. Gen.

Earthwinds will drift eastward in the jet streams, rivers of air seven or eight miles above Earth. Groundspeed: about 75 mph. Airspeed: 0 mph.

Vladimir Dzhanibekov, one of the Soviet Union's most esteemed cosmonauts, is co-captain; and Richard Branson, the millionaire owner of Virgin Atlantic Airlines and Virgin Records, who was on the first Atlantic hot-air balloon crossing in 1987 and holds the Atlantic powerboat crossing record ["Transatlantic Catamaran," Nov. '85], is the pilot. He also has contributed much of the money for the roughly $2 million attempt.

To give the project its best shot at success—and ensure the survival of the crew—required equipping the craft with the latest weather and communications equipment. Satellite communications systems supplied by NASA will provide links to points worldwide. The crew will have global positioning satellite (GPS) receivers to determine the craft's precise location, which can be relayed through the Inmarsat satellite network to project headquarters in Akron. Phone calls and fax messages to and from all corners of the globe will keep the crew wired to people and events (weather updates can be printed out on the fax machine). They'll be in constant contact with a far-flung network of ham radio operators. The best weathermen in the business are supplying navigation advice (see box, Catching the Wind). And a NASA wind-shear instrument on board will gather data for atmospheric researchers.

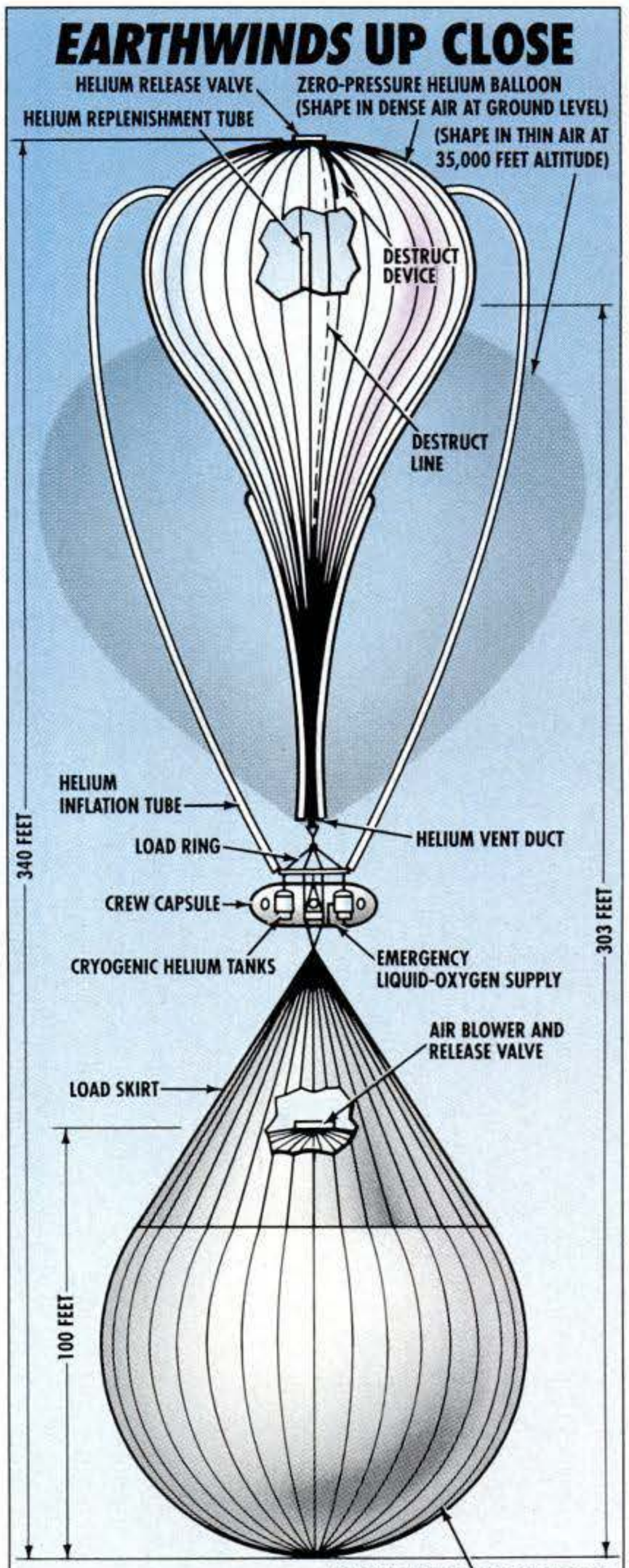
Earthwinds' program manager, Phil Conley, is a retired major general who formerly commanded the Air Force Flight Test Center at Edwards Air Force Base in the California desert. Who on Earth put together such an ambitious and complex venture?

Larry Newman did.

An unflaggingly energetic Boeing 757 captain at America West Airlines, national ultralight champion, world-class hang-glider pilot, and balloonist (he also flies helicopters), Newman has been pursuing the idea of an around-the-world flight for about nine years. What took so long? Aside from fund raising, trying to get permission to fly over the Soviet Union was the biggest roadblock, Newman recalls. "Without that you can't go. Finally, Glavkosmos, the commercial launching arm of the Soviet space agency, invited me to the USSR and told me a Soviet cosmonaut should be on the mission and proposed Dzhanibekov. People at NASA told me, 'This guy has been in space five times, and he's director of cosmonaut training for the whole Soviet Union. He's like Neil Armstrong and John Glenn rolled together.' I thought, 'Sure, I'll fly with him.' "

Newman also recruited the core of the team—about 50 specialist engineers and technicians, many of them located in a group of aerospace companies scattered in the western states—who are working on a frantic timetable to design and fabricate the unorthodox flying machine.

If the truth be told, some of these participants have been overheard attempting to think up punchlines for a joke about three guys who are flying around the world in a balloon that's starting to lose altitude. One guy's from Arizona, another is Russian, and the third guy is British. They're trying to decide what—or whom—to toss out the hatch to lighten the load so they don't end up in the ocean... Punchline development has been proceeding at a snail's pace, though; the engineers are too preoccupied with making sure the three real guys get where they're going. Nobody wants to be the one who built the part that didn't work; they all realize a mistake could cost the crew members their lives.



From takeoff to its 35,000-foot float altitude, *Earthwinds'* helium balloon (shaded area) will quadruple in volume. The anchor balloon's volume will remain constant as air is pumped in or released to adjust the craft's buoyancy.

As sunset approaches on launch day, the airdock's huge clamshell doors slide almost imperceptibly on rollers and rails until the end of the building presents a gaping opening to the sky; the process takes a full five minutes. The crews move the helium balloon and its trailer out the open doors and let the tall envelope slowly rise while cables and winches control its rate of ascent. Gradually the capsule lifts off the ground, as the spherical balloon swings into place underneath it. Now the entire assemblage stands about 340 feet tall.

With the push of a button, the balloon captain severs the restraining cables, and the colossal craft rises silently into the calm evening sky, floodlights on the ground reflecting brilliantly from the upper balloon's silvery sides. Once the helium balloon's mighty lift is unleashed, there is no way to correct a snagged line or some other foul-up that could doom the craft before it even leaves the ground.

At an initial climb rate of approximately 500 feet per minute, the balloon takes about two hours to reach a 35,000-foot altitude, where it catches a northeasterly jet stream that should carry it above Boston in the early morning hours and then out over the Atlantic along the 40th parallel. The craft drifts at a ground speed of about 75 mph, while inside the capsule the crew busily monitors weather reports. The international trio is well aware that the success of the voyage depends heavily on the ongoing meteorological advice they receive.

Up and down are the only directions of flight the balloonists can actively control. After all, *Earthwinds* is predominantly a passive, drifting vehicle that obtains its mobility from rivers of moving air. The only thing the crew can do to

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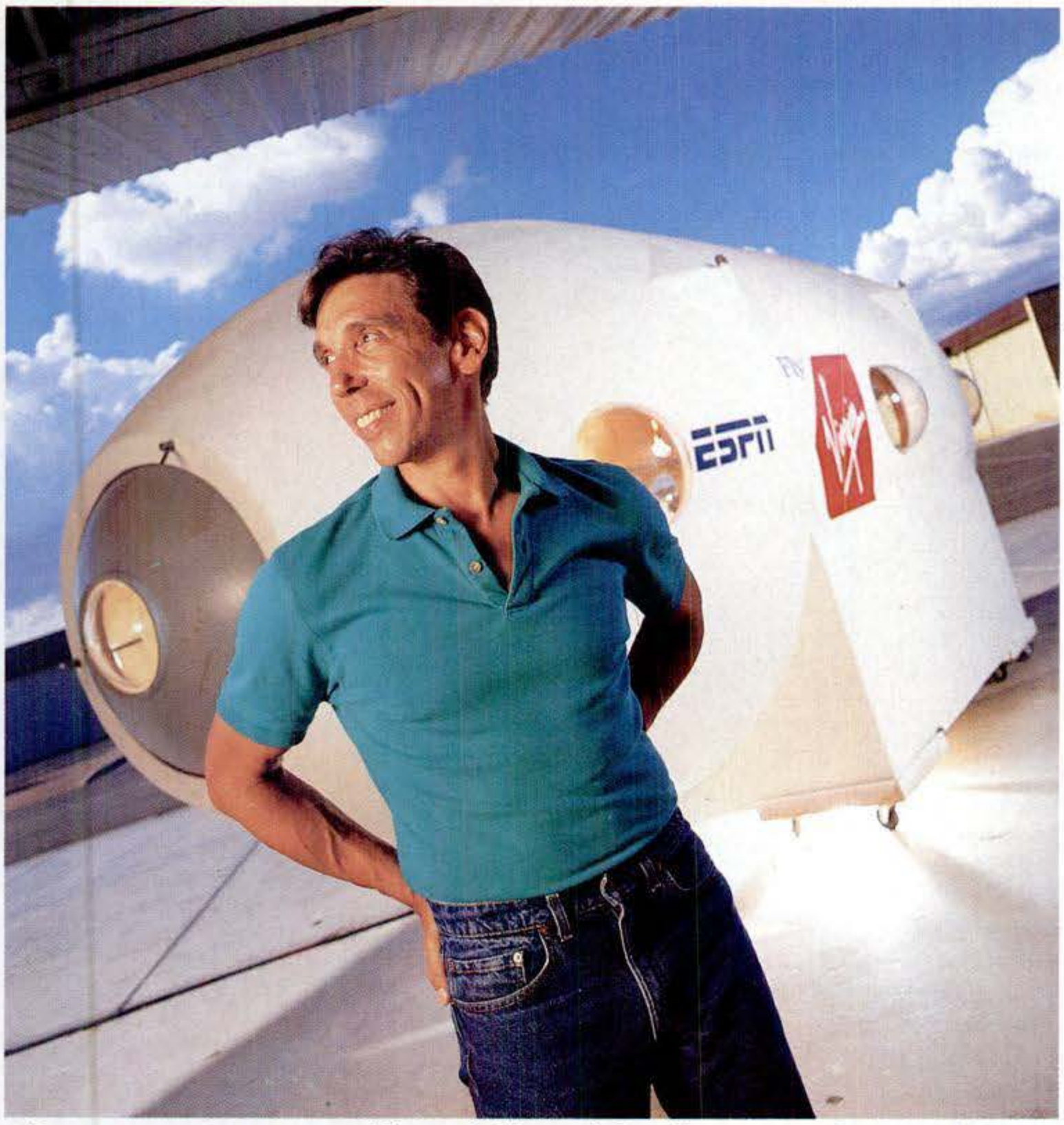

Balloon captain Larry Newman with his newly fabricated glass-fiber crew capsule in Scottsdale, Ariz.

influence its course is manipulate the craft's buoyancy so as to rise or sink into the most favorable wind currents.

Earthwinds looks different from conventional balloons for good reason. Ordinary helium balloons have a theoretical life span of only eight days, far short of the time needed to fly a crew nonstop around the world. Nor can conventional hot-air balloons do the job.

The two types of balloons are limited in endurance for different reasons. A hot-air balloon burns propane almost continuously to generate the heat that gives it lift. Therefore, the notion of designing a hot-air balloon to circle the globe quickly collides with this Catch 22: To carry enough propane, the balloon's hot-air envelope would have to be immense, which would in turn require burning huge amounts of propane to provide enough lift...but that much propane would be too heavy to carry...and so on.

Helium balloons are limited in duration by the daily solar cycle of warming and cooling (see box, The Physics of Balloons). When the sun warms a helium balloon, the gas expands 5 to 10 percent. This extra gas must be released to prevent the balloon from bursting. As the balloon cools at night, the resulting 5- to 10-percent loss of lift causes it to descend. At this point, the solution is to release enough ballast from the balloon to make its weight again equal to its lift, letting it maintain its "float" altitude. This venting-and-ballasting cycle can only be repeated for five to eight days, and then the ballast runs out. A longer flight would require a much heavier supply of ballast with a huge balloon to lift it, which would again increase the ballasting requirement...to a point of rapidly diminishing returns.

Pioneering designers during the past three decades have thought of two ways to extend further the endurance of unmanned scientific balloons.

Earthwinds is the first manned "balloon system" to incorporate these features, says Tim Lachenmeier, the engineer who specified its upended-dumbbell configuration. An admitted "balloonatic" and a member of the tiny world fraternity of about a dozen working balloon designers, he's employed by Raven Industries in Sioux Falls, S.D., one of two companies in the United States that makes huge high-altitude helium balloons for NASA's weather and atmospheric research. These balloons routinely float as high as 130,000 feet.

To make sure he considered all of the most reliable and proven design ideas while drafting the *Earthwinds* blueprint, Lachenmeier consulted a circle of four retired balloon gurus with more than a century of collective experience in government research programs. "The idea is not to reinvent the wheel," he explains, "but to take space-age materials and apply them to existing technology to get the job done. Our number-one concern is safety—to get these guys back alive. With the fast-track schedule we're on, this is a little like doing the whole Mercury program in six months; after all, we're going to orbit the Earth."

The first trick, and the one that makes *Earthwinds* look so outlandish, is coupling a familiar helium balloon with an air-filled "superpressure anchor balloon," the sphere located beneath the crew capsule.

A lighter-than-air balloon rises for the same reason a steel ship can float even though it's made from heavy materials. The ship floats because it weighs less than the volume of water it displaces. A balloon "floats" in the air because the helium or hot air inside it weighs less than the volume of surrounding air it displaces. Similarly, a submarine can rise, sink, or float while submerged, depending on its use of ballast to weigh less, more, or the same as the water its hull displaces.

An air-filled superpressure anchor balloon is a simple and ingenious device that, like the submarine, becomes lighter and heavier with changes in altitude, providing a helium balloon with a "variable ballast" that never runs out. *Earthwinds*' plastic-lined anchor balloon is a nonexpansible fabric sphere constructed with a new ultra-high-molecular-weight polyethylene material called Spectra, which the maker, Allied-Signal, claims has much greater strength and lighter weight than carbon or aramid fibers. A powerful electric fan can pressurize the anchor balloon with air to about 0.5 psi, while a valve permits the pressure to be released.

When *Earthwinds* takes off, the valve on the anchor balloon will be open, nearly equalizing the inside and outside pressures. As the craft nears its cruise altitude the crew will close the air valve. "The anchor balloon always has negative lift—because it's filled with air instead of helium—and it becomes effectively heavier in relation to the thinning air outside as it is dragged higher and higher," Lachenmeier explains. "It's called an anchor balloon because it adds weight to the pay-

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load as it goes up. If designed correctly, it will cause the whole system to come to a float altitude below the point where the helium balloon has to vent any gas, or we have to dump any ballast."

The craft's configuration was partly influenced by a safety concern: In the unlikely event that the pressurized anchor balloon accidentally bursts during the flight, its useless dead weight could be released to fall away only if the sphere were located beneath the capsule. A second consideration was the overhead clearance limitation imposed by the airdock's roof. Locating the crew capsule between the helium and anchor balloons, rather than suspending it beneath both of them, permits pre-launch preparations to be performed in the calm air of the vast structure.

Earthwinds will also be equipped with a supply of liquid helium to replenish any gas lost during daytime venting. Although Lachenmeier has included four cryogenic dewars, or tanks, containing a total of 3,000 pounds of liquid helium, he hopes they will be used mostly as a backup system. "If the anchor balloon stabilizes *Earthwinds*' altitude during the day-night cycle as well as we hope it will, the helium will only be needed to replace the twenty pounds of gas that escapes daily by permeating the molecular structure of the polyethylene balloon film," he says.

Really a set of high-performance thermos bottles, the dewars are being built by Cryogenic Technical Services, a Boulder, Colo., company that designs storage tanks for spacecraft. They are constructed from three shells of aluminum blanketed with a 75-layer insulating sandwich of double-aluminized Mylar film and paperlike sheets of fine glass fiber. The space between the outer two layers of aluminum forms a vacuum jacket; together the thermal barriers will eliminate helium losses due to boiling of the liquid gas. Simple ambient-air heat exchangers on the tank exteriors and outside the crew capsule warm the helium enough to convert it to a gaseous state as it is piped to the balloon.

Lachenmeier figures it's well worth bringing along a ton and a half of spare lifting gas. If it is needed, each pound of liquid helium will provide six pounds of lift, for a total of 18,000 pounds of reserve buoyancy. Any helium not used to replenish the balloon can be released to rise harmlessly to the edge of outer space, while reducing the weight of the dewars.

As the marathon journey unfolds, each of the balloonists will have ample opportunity to play TV director. He can scan an array of five small flat-screen liquid-crystal-display monitors on the wall. The images are captured by five tiny video cameras mounted inside and outside the capsule, then beamed out via a satellite link.

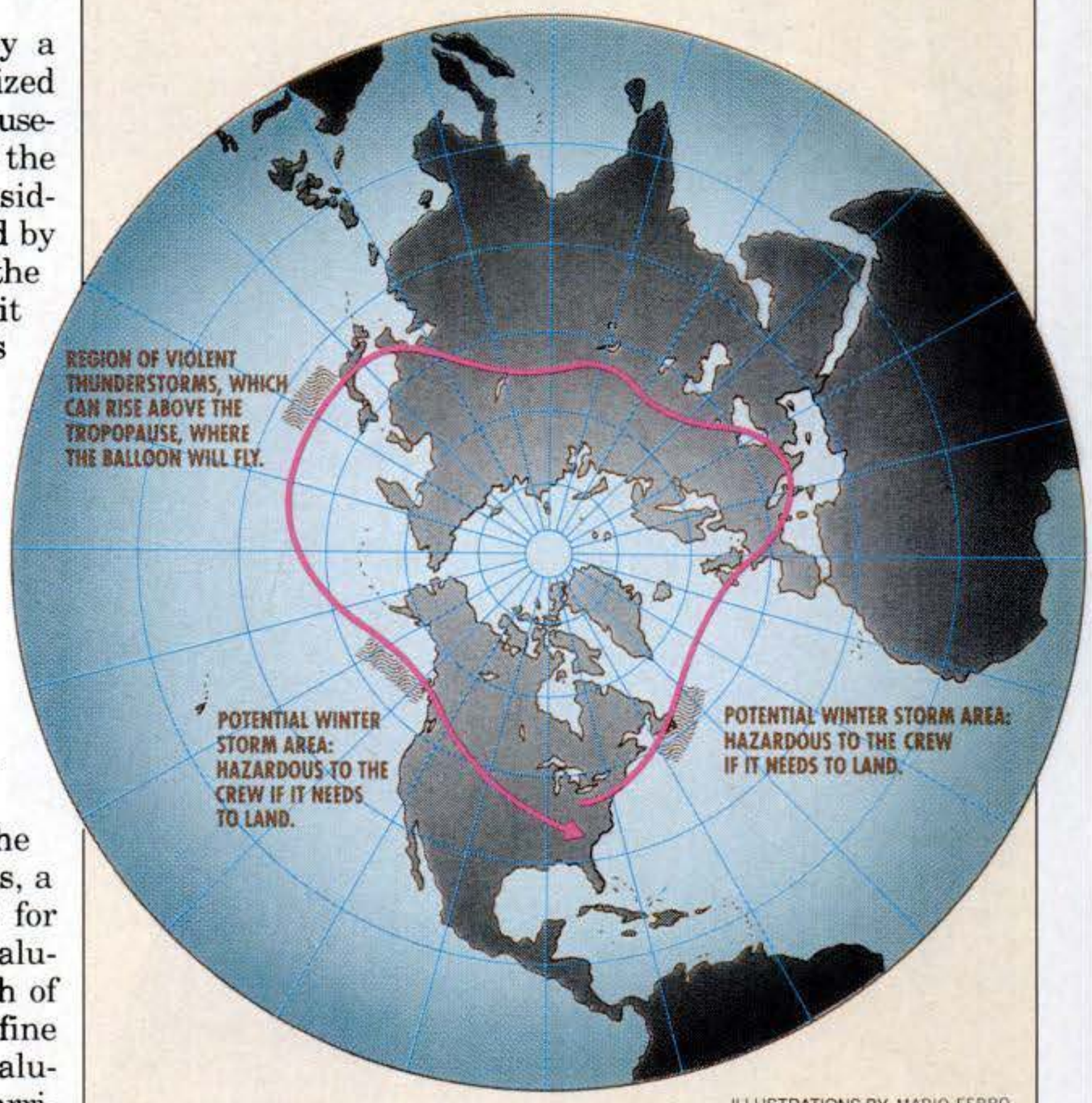
And each evening, ESPN viewers can see news spots of *Earthwinds*' trek relayed by a business jet that will make daily flybys around the balloon at 400 mph.

The activity may divert the crew from dwelling overmuch on the brutal conditions just outside the capsule.

The thin air and minus-50-degrees-F to minus-95-degrees-F temperatures at 35,000 feet would leave the crew members unconscious, freezing, and on their way to suffocation within 30 seconds if they were exposed. Therefore, a climate-control system is needed to make the capsule livable and solve some other problems at the same time.

This lightweight equipment's main component is a small gasoline-fueled engine housed in an insulated box inside the capsule. The engine breathes cabin air and runs for an hour at a time driving an electrical generator that provides current for the capsule's lights and communications equipment, and powers a high-speed electric blower

CATCHING THE WIND


REGION OF VIOLENT THUNDERSTORMS, WHICH CAN RISE ABOVE THE TROPOPAUSE, WHERE THE BALLOON WILL FLY.
POTENTIAL WINTER STORM AREA: HAZARDOUS TO THE CREW IF IT NEEDS TO LAND.
POTENTIAL WINTER STORM AREA: HAZARDOUS TO THE CREW IF IT NEEDS TO LAND.

ILLUSTRATIONS BY MARIO FERRO

When *Earthwinds* rises into a chill winter evening, it will be captive to the whims of the wind. Where exactly will these currents take the balloon? Weathermen can't plot the route the craft will travel with certainty, but they can place a good bet.

The crew plans to position its balloon in the jet stream, where the up-to-250-mph winds can propel it on a fairly direct circum-global route. The trick will be to synchronize the launch with optimal weather conditions—both near Earth and in the tropopause, the layer of air at about 35,000 feet, where the jet stream runs strongest.

In charge of trajectory analysis is meteorologist Bob Rice, director of special projects at Weather Services Corp. in Bedford, Mass. Armed with a history of jet-stream patterns, Rice has traced a realistic route (above) that highlights some hazardous areas through which the balloon must float. To pinpoint a launch date, he will rely on his own forecasts along with guidance from the National Oceanic and Atmospheric Administration, whose supercomputers use complex models to churn out global weather maps daily. "We'll be looking for weather traveling west to east, rather than north or south," he explains. "Then we'll look for a pattern that doesn't have any high-pressure blocks in it, which can stall over one spot for days."

Because winter weather patterns typically flow straighter and stronger than summer ones, time-consuming north-south deviations will be minimized, although even an optimal jet-stream path circles the northern hemisphere "like a bunch of sine waves," Rice says.

Once in the air, *Earthwinds* could face a number of threats. "Thunderstorms can reach up to 70,000 feet," he explains. "That's not normal winter weather, but we want to make sure the balloon isn't aiming at an overachiever." Mountains, especially the Himalayas, create whirlpools in the atmosphere that could suck the balloon downward and slam it against a mountainside. "The plan is to be well north of the Himalayas," Rice stresses, adding that the craft should be at a sufficiently high altitude to clear them if necessary.

"We also worry about icing," he continues. "Frost spread over more than two acres of balloon skin gets pretty heavy. We think that by flying in the tropopause at 35,000 to 40,000 feet where the air is drier, this will not be the problem it is under the tropopause at 30,000 feet.

"You've got to treat the balloon's course like a bowling alley," Rice concludes. "There are gutters on both sides, so just keep the damn thing out of the gutter. Where it goes in between, who cares, so long as it makes a strike."—*Judith Anne Yeaple*

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that pressurizes the cabin's air to the equivalent of an 8,000-foot altitude. During the five-hour periods when the engine is shut down, the box will be opened to keep the power plant and generator warmed to cabin temperature, while shutoff valves block off the system's air-inlet and exhaust-outlet pipes.

Ventilated lithium-hydroxide canisters, long used in submarines, purge carbon dioxide from the cabin air when the climate-control system is shut down. "Recycling the air for a few hours before purging it with the blower is a good thing," Newman says. "It lets some humidity from the crew's breathing build up in the capsule. When we flew across the Atlantic in *Double Eagle II*, I breathed bottled oxygen continuously for thirty-three hours. It took my respiratory system six months to recover from the awful drying effect."

Excess heat from the engine is removed by routing its liquid-cooling circuit through a heat exchanger mounted outside the capsule. Engine exhaust runs in a stainless-steel pipe through the crew's 50-gallon drinking-water reservoir, lowering exhaust temperature enough that the capsule wall's composite resins won't be harmed where the exit pipe passes through it, and using the water as a heat sink that slowly radiates warmth for the crew's comfort. (Ice water will not be served on this trip.)

Electricity from the generator also powers the fan on the anchor balloon, which can pump air into the sphere at a rate that will quickly reverse a temporary ascent to 40,000 feet that could be necessary if weight-increasing ice begins to form on the balloon at its normal float altitude.

The capsule itself is the last component the team expects to suffer any kind of structural failure during *Earthwinds*' flight. Designed and fabricated at aircraft designer Burt Rutan's company, Scaled Composites in Mojave, Calif., the 10-foot-diameter module is built from many laminations of glass fiber. The round doors at each end open from the inside so that cabin pressure continuously forces them shut against soft rubber seals. Larger in diameter than the access ports they cover, the domed doors had to be fabricated inside the capsule after its shell was completed.

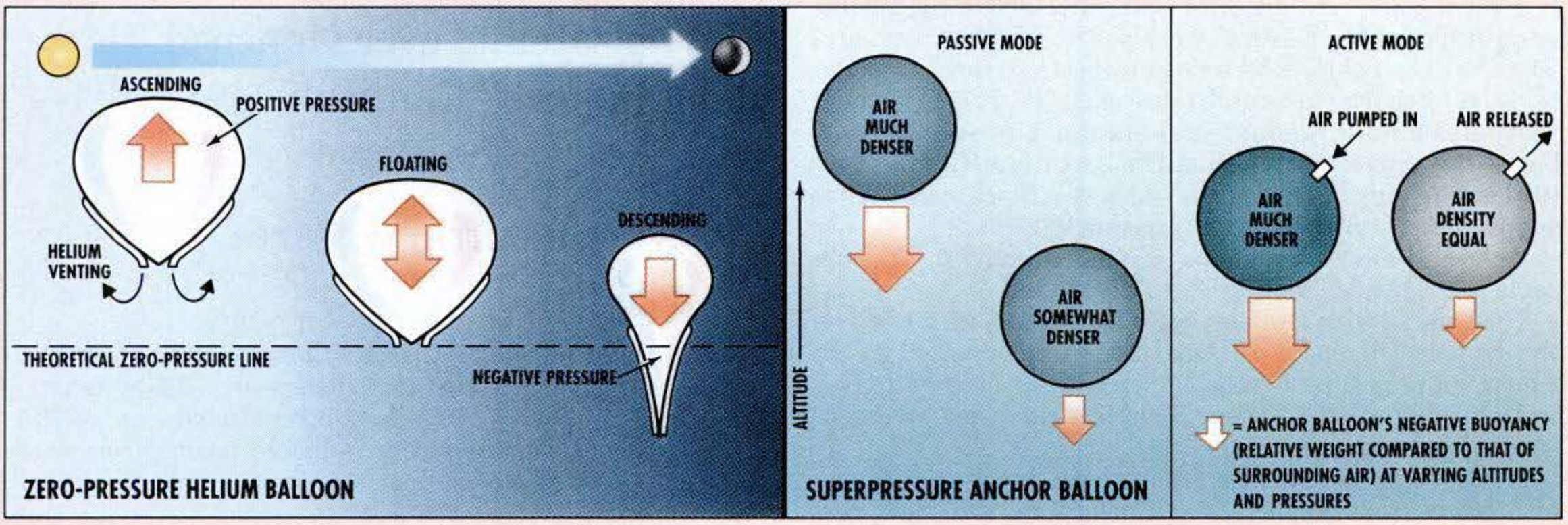
If anything, the capsule is probably much stronger than it has to be. Taking a conservative approach, Rutan called for the addition of reinforcing layers of composite that resulted in a finished weight of 2,000 pounds, a huge increase over its promised weight of 1,200 pounds. The added mass sent a lot of people rushing back to their drawing boards. "This overweight problem is a major one; it ripples through the whole design," Newman laments. "Now we have to start deciding what we're not going to take with us."

After riding the jet streams across the Atlantic and Pacific oceans, Western and Eastern Europe, the Soviet Union, perhaps Japan, and most of North America, *Earthwinds* needs only to land somewhere east of Akron to realize Jules Verne's dream that one day aeronauts would circumnavigate the globe.

A daytime landing in sunny weather would be ideal conditions for spectators awaiting the craft's arrival, but coming down through clouds or even landing at night shouldn't pose a difficult problem. When they are ready for their descent, the crew will choose a likely

[*Continued on page 96*]

THE PHYSICS OF BALLOONS



The device that pulls *Earthwinds* skyward is a helium-filled zero-pressure balloon (above left), so called because the pressure of the gas inside nearly equals the pressure of the air outside. Its envelope is made from four layers of a special high-strength and cold-resistant polyethylene film 1.5 mils thick—somewhat heavier than a dry-cleaner bag. About 100 eye-shaped gores, or strips, of polyethylene joined together by fiber-reinforced "load tapes" form the envelope's plump inverted-teardrop shape.

As an ascending zero-pressure balloon nears its float height, gas expansion due to the decreasing pressure of the thinning air around it causes helium to vent automatically from open-ended ducts at its bottom. A theoretical "zero-pressure line" can be drawn to represent the equilibrium point between the balloon's interior pressure and the outside air; in this case it falls below the duct openings and venting takes place. As the balloon continues to rise and vent helium, it reaches a point where its lift exactly equals its weight—and it floats without losing anymore helium. In this state the zero-pressure line falls at the bottom of the balloon.

A balloon that is descending (due to nighttime cooling and resulting contraction of its helium) assumes a pinched, elongated shape. The zero-pressure line indicates the bottom of the helium bubble, which no longer fills the interior. In this state, the lift provided by the reduced volume of helium is less than the craft's weight; unless ballast is dropped or solar warming occurs, the balloon will continue to descend all the way to the ground.

The superpressure anchor balloon (above right) is a tough-skinned air-filled sphere. In its passive mode, the anchor balloon contains slightly pressurized air that becomes relatively heavier as the helium balloon drags it into thinner, lower-pressure air at higher altitudes. Conversely, it becomes relatively lighter in relation to the outside air as it descends. By effectively varying its weight, the passive anchor balloon rounds off the sharp altitude peaks and valleys ordinarily traced by a helium balloon as it responds to the warming sun and the chilling night.

In the active mode, a fan and release valve add or subtract air from the anchor balloon, causing it to gain or lose weight as the helium balloon begins to ascend or descend. A well-designed active anchor balloon can hold its companion helium balloon at a steady altitude day and night.—*S. F. B.*

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THE TROUBLE WITH HUBBLE

A nine-year-old blunder threatens the mission of the most sophisticated orbiting satellite ever launched. How did it happen? Can Hubble still delve the cosmos?

By ARTHUR FISHER

It should have been the greatest leap forward in astronomy since Galileo. It should have seen farther, deeper, and more acutely into space and time than any instrument the hand of man had fashioned.

Perhaps it will, some day. But for now, the Hubble Space Telescope, an orbiting satellite that whirls around Earth 16 times a day, is a myopic Cyclops, its fuzzy vision caused by a fatal flaw in its 94-inch primary mirror. It is a staggering disappointment to astronomers everywhere, a red-faced embarrassment for NASA and its contractors, a major setback for the backers of big space projects and for the lawmakers who had appropriated the $1.6 billion investment in Hubble, and another blow to the taxpayers—already sensitized by space shuttle failures —whose pockets had supplied the dollars.

"It's a tragedy, it's incredibly disappointing," moaned Sidney C. Wolff, director of the National Optical Astronomy Observatories in Tucson, Ariz. "We had planned to get a whole new view of the universe."

Princeton University astronomer James Gunn, who had hoped to use one of Hubble's high-resolution cameras to obtain revealing images of distant galaxies and quasars, sent an outraged tirade by electronic mail to colleagues, calling the Hubble "fiasco" "probably the most expensive scientific failure in history," and blaming the astronomical community for allowing NASA and the aerospace industry to manage scientific projects.

Sen. Albert Gore, chairman of the subcommittee on science, technology, and space, said: "NASA's eyes are bigger than its stomach. We owe it to the taxpayers to find out what went wrong, how to fix it, and to make sure it never happens again."

The wound was all the more painful because of the great expectations for Hubble. With a bevy of exquisitely sensitive instruments designed to observe in both visible light and ultraviolet, and an orbit 380 miles above the distortions imposed by Earth's atmosphere, Hubble was supposed to detect objects 50 times fainter than those that can be seen with Earth-bound telescopes. It was to answer some of the most fundamental questions in science: How big is the universe? When did it begin? Are there other worlds like ours? What is the mass of a black hole? What supplies the titanic energy of quasars?

Unless Hubble's problems can be overcome, at least some of these questions will go unanswered.

The trouble with Hubble began long before its launch on the shuttle *Discovery* on April 24. First proposed as an American project by Princeton astronomer Lyman Spitzer in 1946, the project has been beset by delays, management snafus, and cost overruns.

The primary mirror took a punishing five years to grind and polish, and when it was finished in 1981 had cost some $3 million more than was budgeted. Various glitches advanced the original 1983 launch date to the fall of 1986. Then came the fatal *Challenger* accident, and all shuttle launches were suspended for almost three years. (Hubble needs a shuttle to be lofted into orbit. It is 42.5 feet long, about the size of a Greyhound bus, and weighs 127.5 tons. It barely fits into the shuttle's huge cargo bay, with just a measly inch of clearance.) After shuttle flights resumed, Hubble was scheduled to go in June 1989, then slipped to February 1990 and then to April. Finally, on April 24, 1990, the most sophisticated astronomical instrument ever built left Earth's surface for a 15-year mission that would bring a new era in our understanding of the cosmos.

But the troubles were not over. They continued with the deployment of the telescope, a day after the launch. The first operation after Hubble had cleared the shuttle bay, but while it was still tethered to the shuttle, was to open its two antennas, uncoil the solar array masts, and unfurl the twin solar panels. Both operations ran into problems.

The antennas are four-foot dishes on 10-foot masts. When ground-based controllers commanded one of the dishes to swivel, it was blocked—before it could complete its travel—by a loop of cable.

The on-board computer immediately "safed" the telescope; it shut the telescope down rather than permit the antenna dish to strain against the cable.

"The telescope is like a hedgehog—a very sophisticated one," says Stephen Maran, a senior staff scientist at NASA's Goddard Space Flight Center in Greenbelt, Md., and one of the co-investigators on Hubble. "If anything goes wrong, it rolls up in a ball. But there is a whole hierarchy of safe modes, from benign ones to very serious ones. In a benign mode you lose the research you were doing, but you don't close the door of the telescope and shut down the power on everything you can think of." In some situations the computer will change the pointing of the telescope to get the solar arrays to face the sun as much as possible. Then it has to close the telescope door to keep direct sunlight from damaging the instruments. The telescope has safed itself at least half a dozen times, Maran says, in a variety of ways.

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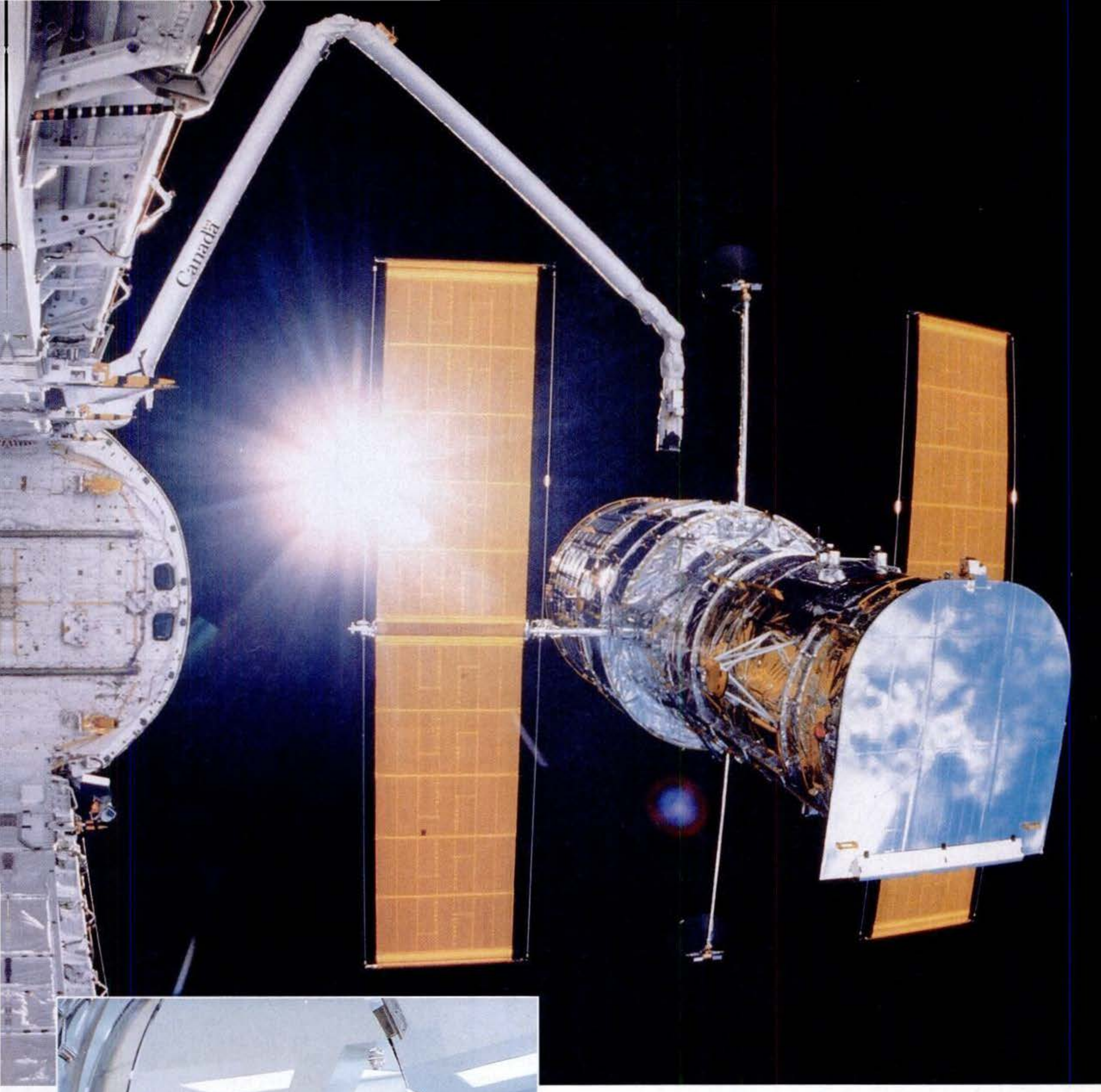

Above: Hubble is freed from the cargo bay of shuttle *Discovery*, with solar panels and antennas deployed. Far left: Technicians inspect the 94.5-inch primary mirror of the telescope after it has been polished. Left: Exploded view of the mirror shows its components. The front and back plates are made of fused quartz and sandwich a honeycomb core. A 2.5-millionths-of-an-inch layer of reflective aluminum is protected by a one-millionth of an inch overcoat of magnesium fluoride.

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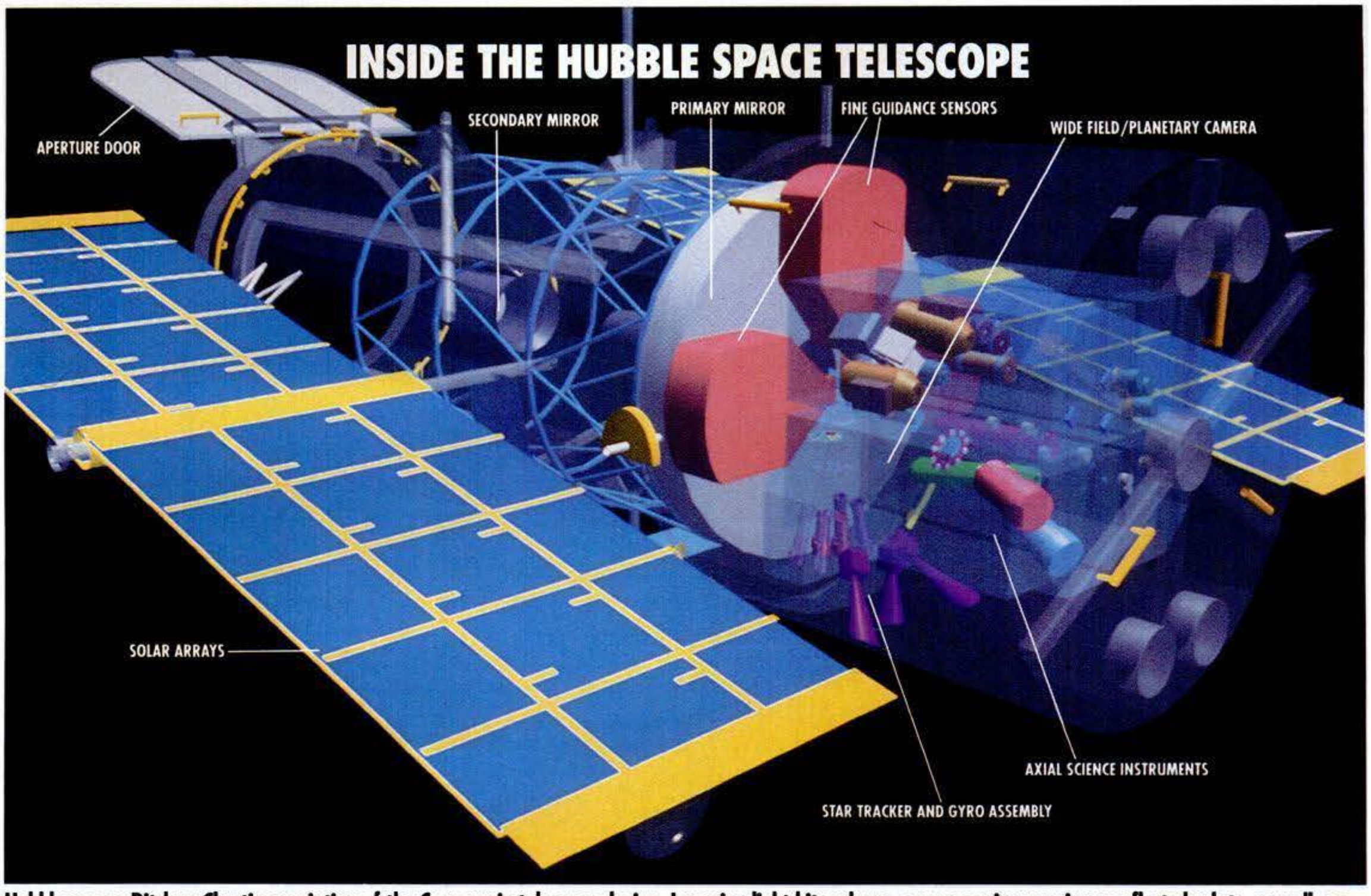

Hubble uses a Ritchey-Chretien variation of the Cassegrain telescope design. Incoming light hits a large, concave primary mirror, reflects back to a small convex mirror, which focuses the light back through an aperture in the main mirror to a bevy of instruments. Both mirrors have hyperbolic shapes.

As a result of that first glitch, the antenna dish cannot swivel through all of the arc originally planned, and the time during each orbit that Hubble can communicate (via the Tracking and Data Relay Satellite System) has been reduced by a small but non-trivial amount. "We just had to rewrite the software," Maran says.

Unfurling the solar arrays also triggered a "safe" because of an event that seemed even more threatening. The arrays, made of $^{1}/_{32}$-inch-thick Mylar film, each eight feet wide and 39 feet long, are propelled into their open state by the uncoiling of a helical metal tape. But the computer detected a tension in one array that was higher than the permitted limit and stopped the procedure.

"That was serious," says Maran. "If the panels don't unfurl, you have to have an EVA [extra-vehicular activity] right away. The battery is dropping rapidly, and you've got to get the solar arrays working to charge it quickly, or hook it up to an umbilical. If the battery goes dead for a couple of hours, there is equipment on board Hubble that will fail, because it gets too cold."

In fact, two of the *Discovery* astronauts started suiting up and rebreathing oxygen. But when the crew looked out a shuttle window, they could see no sign of the extreme stress in the panel the computer had signaled. They decided to override the computer and continue the operation, which was successful.

Other problems arose during Hubble's first days and weeks in orbit. Astronomers and engineers puzzled over the telescope's apparent confusion over just which stars to aim at. The fault lay in devices called fixed-head star trackers, three little telescopes in the mid-section that are responsible for first approximations to precise aiming. (By contrast, the three fine guidance sensors are capable of locking on to a star that subtends an angle of only 0.007 arc second—equivalent to the diameter of a

HUBBLE'S TROUBLED PAST

1923—German space writer Hermann Oberth speculates for the first time on the possible value of placing an astronomical telescope in Earth orbit. But the idea lay dormant until the rapid development of rocketry in World War II.

1946—Princeton astronomer Lyman Spitzer writes a study titled "Astronomical Advantages of an Extraterrestrial Observatory," noting that only a telescope above Earth's atmosphere can record ultraviolet radiation from heavenly bodies.

1962—A group of scientists organized for NASA by the National Academy of Sciences to study the future of space science recommends the development of a large space telescope as a long-range goal of the nation's space science activities.

1973—NASA selects a group of scientists to consider both the basic design of the telescope and the instruments it will have.

1974-78—The space telescope program is in danger of being postponed indefinitely or being canceled altogether as the result of repeated Congressional and executive budget reviews.

1977—Congress finally approves NASA's recommendations and authorizes the Large Space Telescope. Perkin-Elmer is chosen to build the optical assembly and Lockheed Missiles & Space Co. is chosen to build the support structures and assemble the components of the complete satellite. Launch is scheduled for 1983.

1983—Science instruments are delivered to NASA for testing, but completion of the observatory has fallen behind schedule. The program is renamed the Hubble Space Telescope after Edwin P. Hubble, discoverer of the expansion of the universe.

1985—Assembly of the spacecraft is completed, and launch is rescheduled for 1986. Technical problems cause postponements.

1986—The shuttle *Challenger* explodes, killing its crew of seven astronauts. Without shuttle flights, Hubble is grounded indefinitely.

1989-90—The Hubble launch slips from June 1989 to April 1990.

April 24—Hubble is launched aboard *Discovery*.

April 25—The telescope encounters problems with the deployment of its solar panels and antennas. Soon other problems—with vibration and pointing stability—emerge.

Mid-June—Hubble scientists learn that the telescope's optics do not focus properly.

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dime in a window of the John Hancock Building in Boston as seen from the top of the Washington Monument.)

"The fixed-head star trackers were not working well," says Maran. "They were homing in on the wrong stars. They depended for orientation on a star catalog that had been assembled by astronomers, and it turned out that the catalog had mistakes that needed to be corrected. Also, all three were supposed to have square fields of view, but one of them was delivered with a round field of view, accompanied by an apologetic note from the manufacturer. But the note got lost in the system over the years. So this star tracker was missing stars in the corner of the field because it had no corners."

These errors, and the fact that the star trackers are more sensitive (and thus more easily confused) than they were supposed to be, are being compensated for by changes in the data base of the ground system.

More grievous is a problem that was still plaguing Hubble in late July: vibration. Every hour and a half in its whirl around the globe, the satellite crosses the terminator—the boundary between night and sunlit day. The temperature change from bitter cold to warmth happens in a span of just 90 seconds; this "snap" starts the solar panels jiggling, perhaps beginning in the helical metal tapes; and then the whole telescope begins to tremble.

"That can cause you to lose pointing control," says Maran, "and you certainly can't keep a star in a tiny slit. This is the first problem that made people in authority on the space telescope project really worried."

Jean Olivier, the deputy project manager for Hubble and the mission's chief engineer, made plain what the worry was. Unless the vibration problem is solved, he said, "we do not have a space telescope."

Hubble's designers anticipated some vibration as being inevitable, and incorporated compensation for it: a closed loop system with gyroscopes and inertia wheels. But the amplitude and frequency of the thermally induced vibration amount to more than the present control system can cope with. The hope is that new computer software being written by Lockheed (builder of the spacecraft itself) will reduce the vibration by at least a factor of 60—perhaps as much as 100—and make it possible for the telescope to do useful work.

Telemetering new software up to Hubble is not without risks; there is concern lest damaging errors be introduced. "It's like changing a spark plug while driving down the road," says Olivier. "You've got to be careful."

All of these troubles—the vibration, the pointing confusion, the problems with the antennas and solar array—were but premonitory rumbles compared with the earthquake that rattled the space establishment: the discovery that Hubble's vaunted vision was so blurred the mission would not be able to realize more than a fraction of its scientific goals. It was as if an eagle had turned into a bat.

The discovery came in June, after the telescope had finished its coarse-focusing phase and was entering the critical fine-focus phase. Ground controllers took a series of six images of the bright star Iota Carina with the wide field/planetary camera, or WFPC. This visible light camera operates in two modes: a wide-field mode for imaging galaxies and quasars, including those billions of light-years from Earth; and a planetary mode for imaging the entire face of a solar system planet (except Mercury, which is too close to the sun) in a single exposure.

For each of the six exposures, made in the wide field mode, controllers commanded the 12-inch convex secondary mirror to move to a different position along the optical axis—nearer or farther from the primary mirror. One of these images should have shown a dramatically improved focus. But to the dismay of controllers and astronomers alike, the image could not be sharpened, no matter how the mirror was moved.

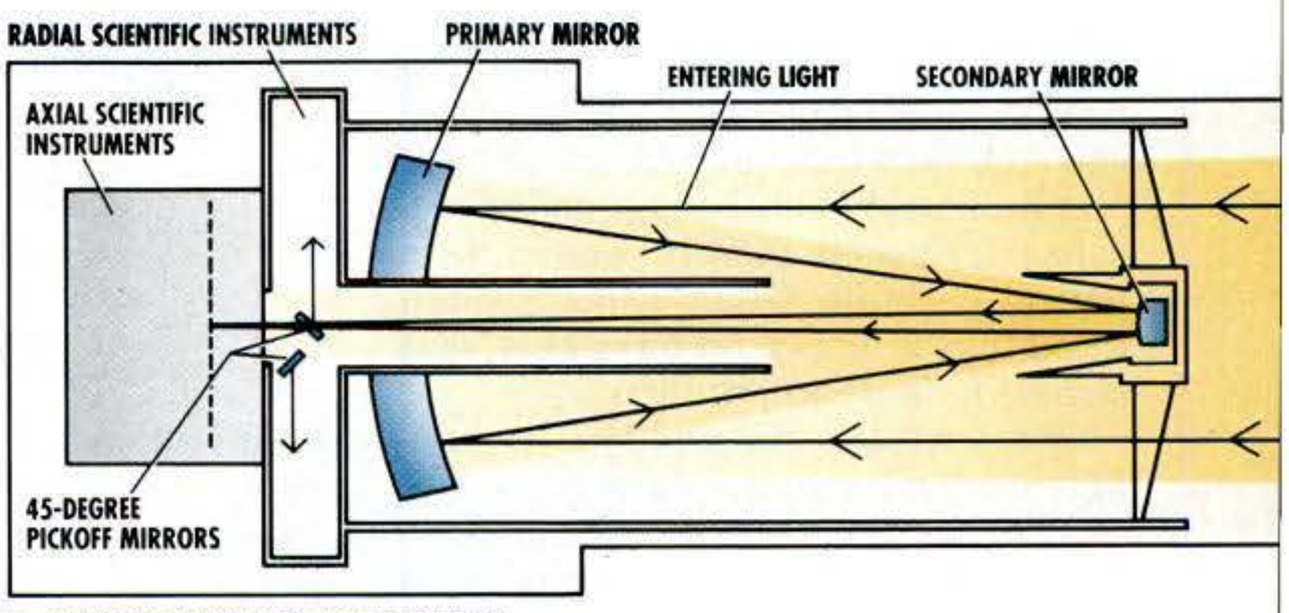
Steve Maran recalls being alerted on the morning of June 26 to devote all day and all night to studying "what an image quality this bad would mean for our science." The next day NASA released the bad news.

The nature of the flaw was immediately apparent from the blurry images. Star pictures that should have been points were instead surrounded by a fuzzy halo, characteristic of the optical defect called spherical aberration. With it, the light rays reflecting from a mirror (or passing through a lens) do not all focus at the same point. Parabolic mirrors are supposed to eliminate spherical aberration; both of Hubble's mirrors are hyperboloidal, a shape that avoids both spherical aberration and another aberration called coma off-axis.

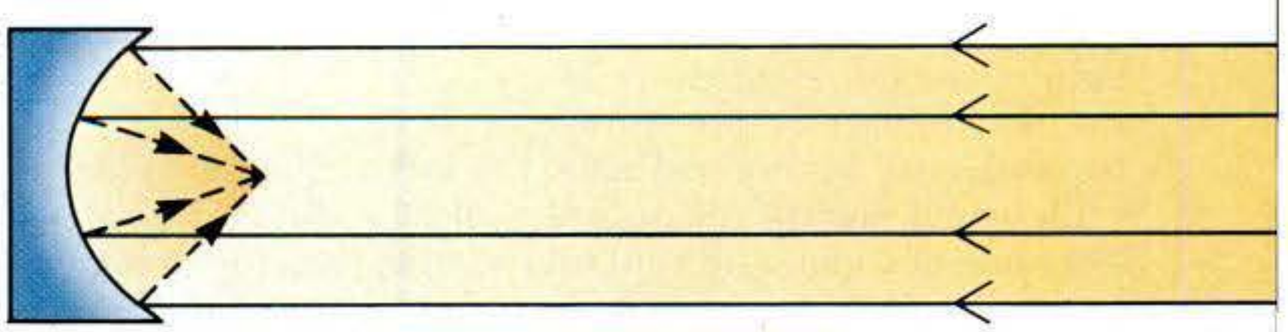
NASA engineers created computer simulations of images that would have resulted if Hubble's mirror system had different degrees of distortion in its curvature. When they ran one that corresponded to the spherical aberration resulting from a deviation of only one-half a wavelength of light—about one-fiftieth the width of a human hair—it closely matched the actual Hubble pictures. From further computer analyses of the faulty images, it seems almost certain that the flaw is in the big primary mirror, not the small one, and not in both.

James Westphal of the California Institute of Technology and the principal investigator on the WFPC called the flaw a "textbook, classic" example of spherical aberration. It is so symmetrical that NASA experts believe it must

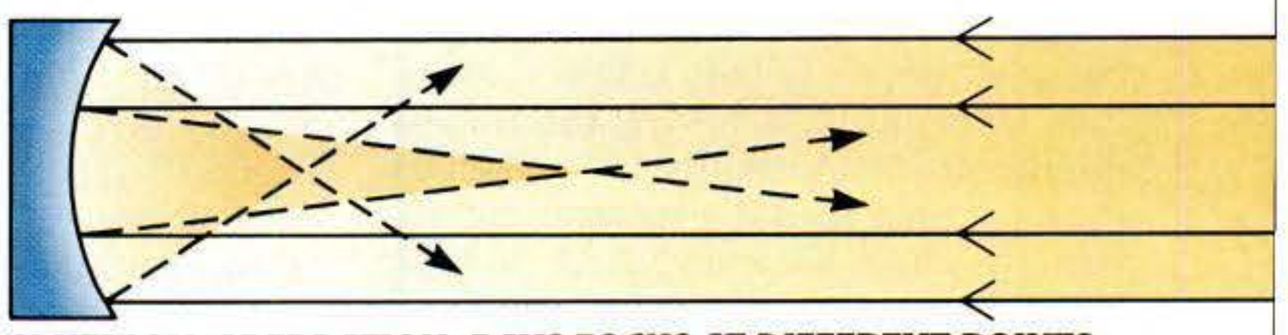
HOW HUBBLE SHOULD WORK



TELESCOPE'S OPTICAL PATH



CORRECT FOCUS OF HYPERBOLOIDAL MIRROR: ALL RAYS FOCUS AT ONE POINT



DANA BERRY, SPACE TELESCOPE SCIENCE INSTITUTE

SPHERICAL ABERRATION: RAYS FOCUS AT DIFFERENT POINTS

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have been ground in, and not a design error.

Testifying before Sen. Gore's subcommittee, Lennard Fisk, NASA's chief scientist, said that the primary mirror seemed to have been as smoothly polished as specifications called for—no bumps or pits taller than a half-millionth of an inch. Instead, he said, there seemed to be a systematic, symmetrical error in the mirror's curvature. "In other words," he said, "it appears to be perfectly wrong."

"We suspect," Olivier said on June 27, "that the methods used to measure the figure [curvature] of the mirror during manufacture, which are very complex, resulted in the mirror being very precisely made, but to the wrong figure."

The blow to the Hubble team was particularly stunning because, as Maran says, "It was the last thing in the world anyone thought would be defective.

How could such an error go undetected?

The whole question is an exceedingly complex one, because of the exotica of mirror testing, an art more arcane than necromancy. Some experts have lambasted NASA for not doing an "end-to-end" or "all-up" test, in which both large and small mirrors would have been tested as an ensemble. NASA's Olivier responded that the agency had considered but rejected such a test, which he said would have cost hundreds of millions of dollars because a special facility would have had to be built. Other experts countered that a test could have been performed for only $10 million.

The irritated sensibilities of lawmakers and astronomers were not soothed by the revelation that Eastman Kodak Co., the losing bidder on the Hubble telescope, had included in its bid a $10 million test that would have detected the flaw. Moreover, the Kodak proposal called for another company, Itek Optical Systems, to build a second, identical primary mirror. Having two different mirrors and two different testing methods, the bid said, would ensure the accuracy of at least one of them, and that one would be used on Hubble.

In fact, NASA ordered a backup mirror from Eastman Kodak while awarding the telescope contract to Perkin-Elmer. The former chief Hubble scientist, C. Robert O'Dell (now of Rice University), believing the Kodak mirror to be optically superior to Perkin-Elmer's, urged its use, but he was overruled because NASA administrators felt it would poison the project to choose the losing bidder's product over that of the prime contractor. That backup mirror now resides in a wooden crate in Danbury, Conn.

What makes the story even more complicated is the role of the military, spy satellites, and a rumored high-level tug of war between NASA and the Pentagon. It is well-known that spy satellites, also built by Perkin-Elmer, use a telescope similar to Hubble's, with the difference being that theirs is pointed down instead of up. Those telescopes are routinely tested end-to-end at ground-based facilities.

William Burrows, an authority on spy satellites and author of the book *Deep Black—Space Espionage and National Security*, says "It mystifies me why the Hubble telescope wasn't tested end-to-end. It was assembled by Lockheed in the same building used to assemble the spy satellites. It could and should have been tested in the same way they are."

"It appears to be perfectly wrong"

Because of the shroud of secrecy over space espionage, the facts may never be wholly known. But there are reports that the Air Force offered NASA the use of such a test facility some 10 years ago, but was refused, possibly because the military wished to impose too stringent security.

NASA has appointed a commission chaired by Jet Propulsion Laboratory director Lew Allen to investigate the mirror error. It includes both NASA and non-NASA experts, such as Roger Angel, head of the mirror laboratory at the University of Arizona's Stewart Observatory. Their task will involve following a lengthy paper trail of records both from the mirror maker, Perkin-Elmer (now Hughes Danbury Optical Systems), and from NASA's Marshall Space Flight Center. The commission's labors will probably not be completed and a report rendered until October.

Allen has promised that his review panel would disclose not only how the mirror fiasco came about but also who was responsible. "We know the most likely outcome of our investigation will be a result that is very embarrassing to someone or some group." The question is whether the fault lies with the contractors, NASA, or both.

Wherever the buck stops, the mirror's imperfection has led to a hurried reassessment of what science Hubble is still capable of. "We were expecting to have seventy percent of the incoming light focused within a circle whose diameter is a tenth of an arc second," says Maran. "We designed our scientific instruments around that specification and the whole science program. What we're getting now is about ten percent going into that circle and seventy percent into a halo of about 0.7 arc second.

Most severely affected are those programs—and instruments—involved in the imaging of the faintest objects and those demanding the highest degree of spatial resolution —the ability to discriminate between two close-together stars.

Worst off is the WFPC. Edward Weiler, Hubble program scientist at NASA headquarters, stated dejectedly that the instrument—meant to be Hubble's workhorse—would be so degraded that it might simply be turned off, and its heavy share of observing time—some 40 percent—allocated to other instruments that suffered less impairment.

The spectrographs, which don't form images, are less affected. But NASA spokesmen, in an initial rush to take some of the curse off the bad news, may have downplayed the losses that these instruments too will endure.

"NASA has said that our own instrument, the Goddard High-Resolution Spectrograph, will be least affected," Maran says, "and that we can do about seventy-five percent of the science we intended. What that doesn't tell you is that because we won't be able to get all the light from a star it will take much longer to do it, and it won't be done as well."

Can Hubble be fixed? The answer is a conditional yes.

The working plan for repairing Hubble's misty vision is not to fix the telescope as such, but to put corrective spectacles in the form of small curved mirrors on new instruments that will replace the present ones. Because the aberration does seem to be a straightforward one, NASA optical scientists and engineers should be able to deduce the right "prescription" from the images obtained by the wide-field and

[*Continued on page 100*]

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REINVENTING THE WHEEL

By MARCELLE M. SOVIERO

It may resemble something from science fiction, but this three-spoke wheel is likely to draw attention for more reasons than its looks.

Called the Aero Wheel, it was recently introduced by Specialized Bicycle Components of Morgan Hill, Calif. Aiming to make the fastest bicycle wheel ever, company founder and president Mike Sinyard —a cycling enthusiast—teamed up with Mark W. Hopkins, a fellow cyclist and senior engineer at Du Pont's Advanced Composites Division.

They set out to produce a wheel for racing bikes with the speed of a solid disc wheel, but without the disc's shortcoming: instability in crosswinds.

Because it has a large surface area, a disc wheel mounted on the front of a bicycle can make steering difficult because of side-wind forces. A conventional spoke wheel avoids this problem because of its large open area, but the spokes can generate turbulence, which cuts speed.

To create a better wheel, the designers borrowed some tricks from aircraft design. "If we were designing an airplane, we would have gone through the same steps we went through for the wheel," says Hopkins.

Using data on coefficients of drag from NASA tests on airfoils, they created a wheel with three spokes. The spokes act as airfoils to cut drag and are optimized for speeds of 25 to 35 mph. The rest of the wheel's area is open to allow wind to pass through. The airfoil data were then fed into a computer, which guided a milling machine to cut a full-sized prototype.

This image, from Du Pont's Cray supercomputer, shows a computer model of the wheel.

Next the designers needed to find the right material for the wheel. Knowing that only composites could offer both high strength and low weight, Frank Principe and Kevin Kelleher, also Du Pont engineers, used Du Pont's Cray supercomputer to analyze different combinations to see how they would affect performance.

The result is a wheel made of carbon fibers, Kevlar aramid fiber, and an epoxy resin. The aluminum rim can take sew-up or clincher-type tires.

Even though the wheel is made of composites, it still weighs about 300 grams more than standard spoke wheels, but this shouldn't be a problem. "The aerodynamic advantages outdo the weight disadvantage," says Hopkins. He says computer predictions based on data from wind-tunnel tests show that, all else being equal, two Aero Wheels on a bike will cut 10 minutes off a racer's time in a 100-mile race. Of course, this is not without a price—$750 per wheel. PS

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You can't reduce stomach fat by exercising abdominal muscles alone.

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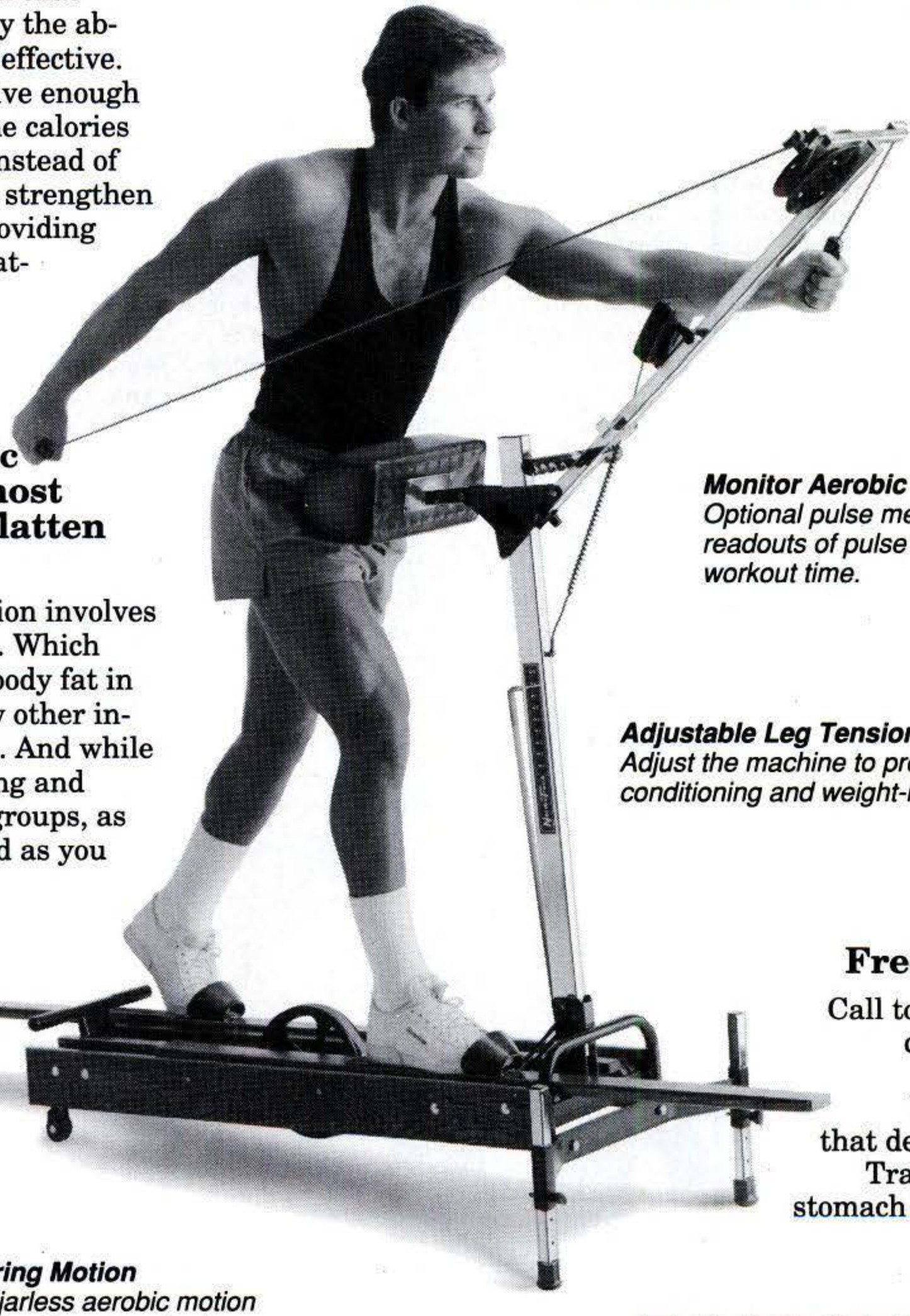

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AUTO TECH '91

ANTILOCK BRAKES FOR $400

A revolution in the availability of electronic antilock braking systems will bring safety advantages to the buyers of mainstream domestic cars in 1991. Once costing upward of $1,200, the price of ABS is expected to fall below $400 soon. The first of a new generation of reasonably priced antilock systems is Delco Moraine's ABS VI, installed as standard equipment on some 1991 models of the Buick Skylark, Oldsmobile Cutlass Calais, and Pontiac Grand Am. The eagerly awaited Saturn coupe and sedan from General Motors will also be available with ABS VI when the car debuts in late fall.

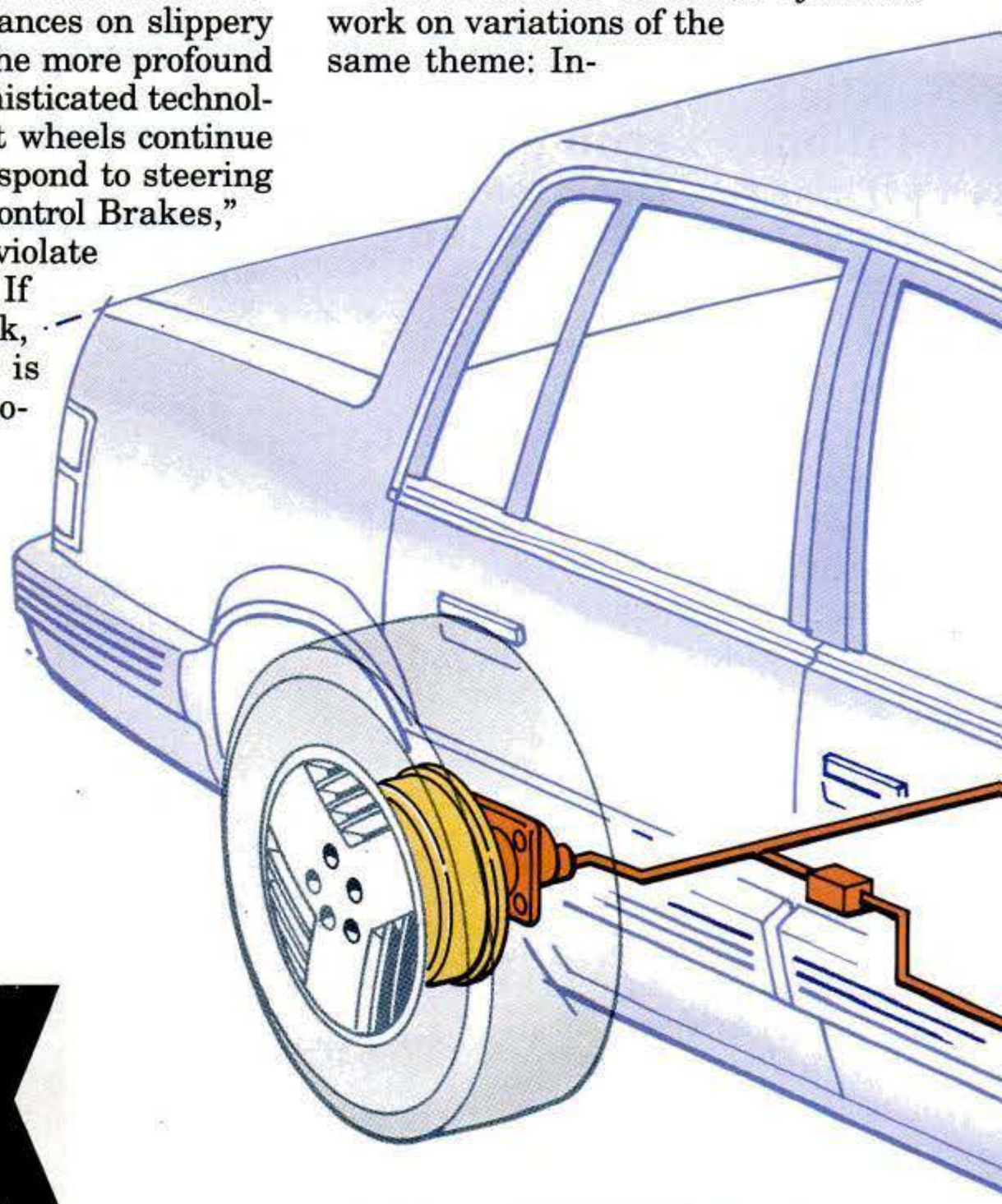
Because the Delco Moraine antilock brake system will not be offered as a stand-alone option in 1991, the actual price tag is impossible to determine. Sources at GM insist that the inclusion of ABS VI as standard equipment will not cause sticker shock by inflating the overall price of those models. And, when the system is available as an added-cost option, the price to the car buyer will likely be between $350 and $400. This is the first tangible development in fulfilling GM's promise of making ABS available on every model by 1995.

Chrysler and Ford are less exact as to their target dates and prices for across-the-board ABS, but appear committed to having this safety device available for all car buyers by the middle 1990s. Replacements for the present generation of Japanese compact sedans are expected to incorporate antilock systems that are already available in the home market.

The ability of ABS to prevent wheel lockup in a panic stop by precisely modulating brake pressure is well-known, having been available to buyers of sport and luxury cars in this country for six years and for more than a decade in Europe. For the average driver this has meant reduced stopping distances on slippery road surfaces, but the more profound outcome of this sophisticated technology is that the front wheels continue rotating and will respond to steering inputs ["Now: Skid-Control Brakes," Nov. '84]. You can't violate the laws of physics: If the front wheels lock, the car's trajectory is controlled by its momentum, and wrestling with the steering wheel has little or no effect. ABS goes beyond advances in passive safety, like seat belts and air bags, by adding an active dimension, hopefully enabling a driver to prevent an accident, not just survive one.

Much like recent trends in personal computers and home electronics, the pace of technological growth in ABS makes the new generation systems available to a wider group of buyers. Specifically, Delco Moraine engineers were able to reduce the cost of ABS VI by simplifying the hardware and devising an innovative hydraulic modulator, the device that pulses brake fluid pressure to prevent wheel lockup. As a secondary benefit, the action of the ABS VI system has little of the brake-pedal pulsation that's present in most systems.

Conventional antilock systems work on variations of the same theme: In-



A new design strategy is making the safety advantages of ABS more affordable.

By BRIAN NADEL

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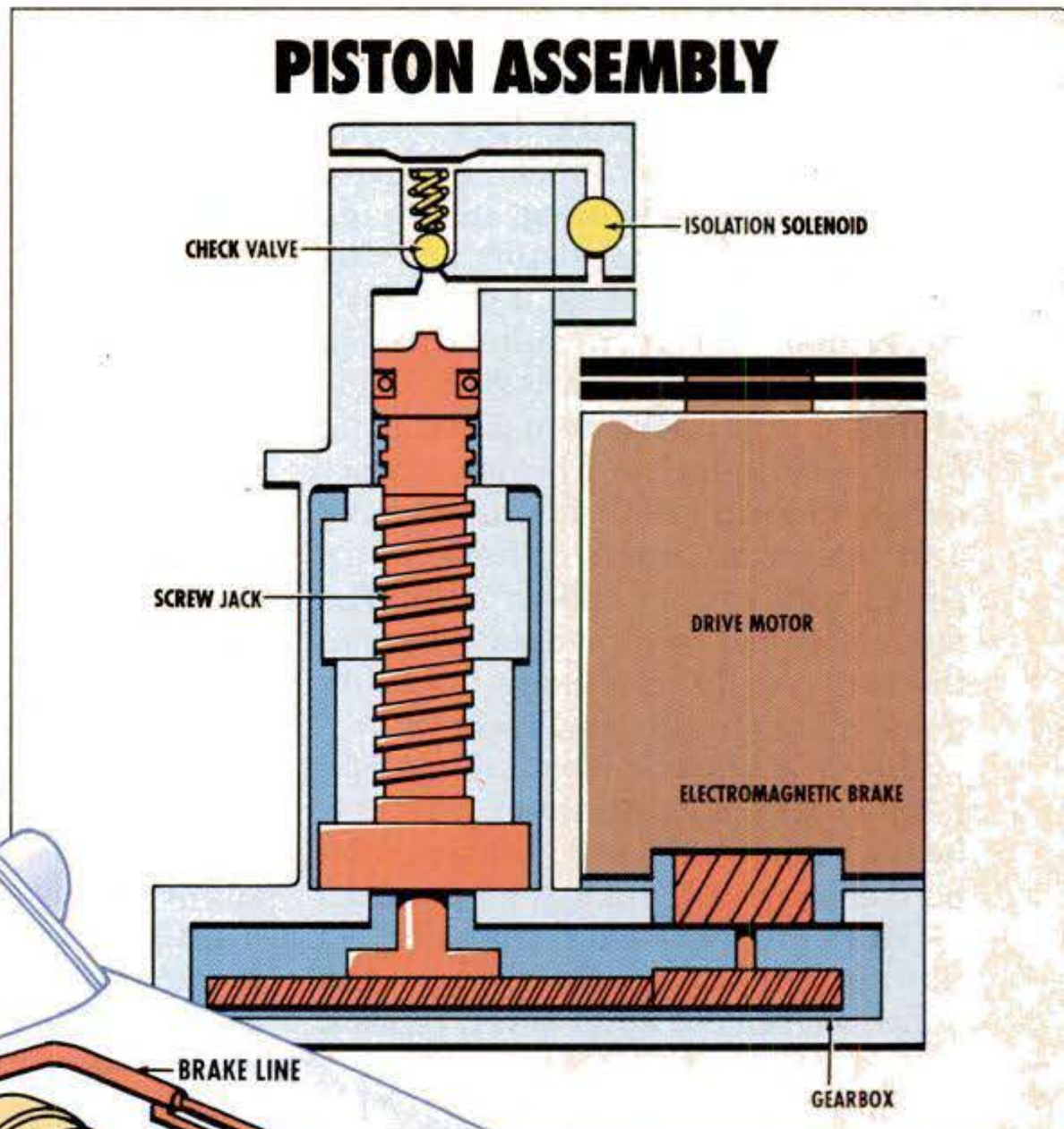
ductive wheel speed sensors detect the onset of wheel lockup by constantly looking for one wheel getting out of step with the rest. At this point, control of the brakes is effectively taken over by the ABS digital computer and hydraulic modulator until the car stops, the tire regains traction, or the driver releases the brake pedal.

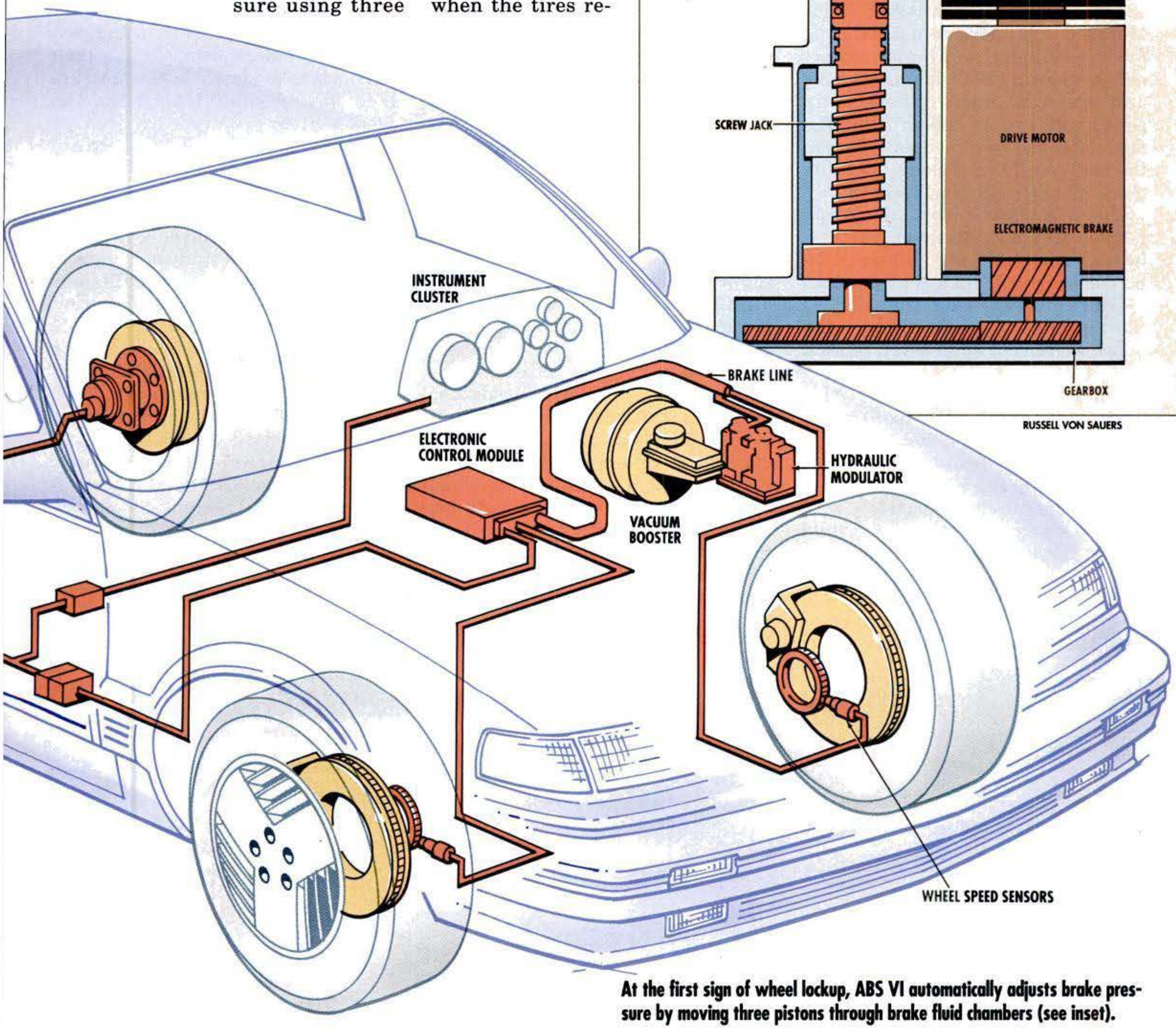
In most ABS installations, hydraulic pressure to actuate the brakes is alternately pulsed by the rapid opening and closing of solenoid valves to blow off pressure individually for each wheel, or, in some cases, for both rear wheels together. Brake fluid that flows through the solenoids is repressurized and stored in an accumulator for the next braking. The driver feels pressure returning to the system as pedal pulsations.

By contrast, Delco Moraine's ABS VI adjusts brake-line pressure using three motor-driven pistons in the hydraulic modulator. When the computer decides that antilock control is needed, an electromagnetic brake on each motor is released, allowing them to spin independently to 7,000 rpm (see illustration). The motor drives the pistons downward through a gearbox and screw jack mechanism from the full upright position, seating a check valve that seals the system; a solenoid isolates the action at the modulator from the brake pedal. All the driver feels is a gentle quivering of the pedal, not the staccato sequence of solenoid valves popping open and closed.

The more the pistons move down, the larger the chamber's volume, reducing brake pressure along the way; when the tires regain adequate traction, the pistons move up to reapply the brakes. As an example, on the Pontiac Grand Am there is a motor pack, chamber, and piston for each front disc brake; the rear-wheel drum brakes are separately monitored, but the brakes are pulsed in tandem.

"Theoretically this system provides us with better brake control because there is a relationship between the current the motor draws and the pressure in the system that is used in a feedback loop," explains William Gillespie III, Delco Moraine's techni-





At the first sign of wheel lockup, ABS VI automatically adjusts brake pressure by moving three pistons through brake fluid chambers (see inset).

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cal director for antilock brakes and traction control. This added control allowed designers to program the pistons to make partial excursions and even to adjust their speed to fine tune stops. Gillespie sums up the critical difference: "We're not locked into the on-off action of the solenoids. We can adjust brake pressure to exactly where we want it to be."

Part of the cost reduction for Delco Moraine's ABS VI is based on it being an adjunct to the car's standard vacuum assisted brakes, not a self-contained, fully hydraulic antilock brake system. This allowed Delco Moraine engineers to use existing master cylinder and brake components, reducing both manufacturing and assembly costs. There is an added bonus of an add-on ABS: The modulator can be placed anywhere in the car, greatly increasing flexibility in an era of crowded engine bays.

Under a worst-case braking scenario—let's say, slippery surface, heavy vehicle, and worn brakes, compounded by very high temperatures—Gillespie says that the ABS VI now installed in new models can pulse the brakes up to seven times a second.

Other manufacturers of ABS equipment—notably Bendix Automotive Brake Systems, Robert Bosch Corp., and ITT Teves—believe that the system needs to respond about twice as fast to deal effectively with treacherous road conditions. While two or three braking cycles per second is appropriate for wet asphalt, a panic stop on ice might require 10 to 15 cycles per second to maintain control. Many current antilock systems have the ability to pulse the brakes at that level, among them the Bosch ABS 2U used on current Mercedes-Benz models.

Lately, the emphasis at Bosch's Broadview, Ill., research facility has been on reducing cost without compromising the reliability or performance of the unit. Says Josef Mack, Bosch's manager for antilock brakes and traction control, "We've been looking at areas that were designed with the belt and suspenders approach. In some instances we think we can get by with just suspenders and not have our pants fall down."

In addition to reducing the number of components from 140 in the original 1978 design to 40 today, the evolution of three specific parts has brought the car buyer's price for the Bosch system down to about $800: replacing a custom-designed integrated circuit with a microprocessor, which is less expensive than an IC; going from an expensive forged-aluminum modulator housing to an extruded part; and substituting plastic wheel speed sensors for stainless-steel parts. Also, the solenoids have been redesigned for ease of manufacture.

Bendix of South Bend, Ind., a supplier of antilock brakes to Chrysler, has gone a step further. By redesigning the solenoids to cut actuating time in half (from 10 to 5 milliseconds) they were able to eliminate four solenoids in their new Antilock 6 design. Reducing the size of moving parts while increasing the magnetic power of the solenoids was key to the performance improvement.

With ultra-fast solenoids at their disposal, designers were able to eliminate the "hold" solenoids that had been used to stabilize pressure between brake pulses. These faster-acting modulation solenoids are programmed to flutter rapidly between the opened and closed positions, mimicking the hold function.

Antilock 6 uses four solenoids to modulate fluid pressure and two solenoids to isolate the master cylinder from the modulation unit. One of the engineering goals for Antilock 6 was reducing brake-pedal movement to the minimal amount.

Chrysler reports that Antilock 6 will be an option on the '91 Dodge Spirit and Daytona, the Chrysler LeBaron sedan, coupe, and convertible, and the Plymouth Acclaim for approximately $750—a $150 savings over the Antilock 10 unit on the '91 minivan.

Two other novel ABS approaches are restricted to Europe. The Lucas Girling Stop Control System relies on a belt drive from each of the car's front wheels to convey both speed information and power the all-mechanical system that pumps the brakes ["Breakthrough in Anti-Skid Technology," Sept. '86]. SCS has yet to achieve widespread acceptance and is only available on certain Ford Escort models in Europe. The FaTec C2 ABS is another attempt at reducing cost by using pressure pistons rather than solenoids to modulate brake pressure (see box, Mechanical ABS: the Smooth Stop).

Is ABS a panacea? No, because ABS can never be better than the car's base brake system, and a trained test driver can outperform ABS with subtle movement of the brake pedal. But a study of European accidents indicates that collisions could be reduced by 10 to 15 percent with widespread acceptance of ABS. If these data are applicable to the United States, where driving conditions are admittedly different, 5,000 deaths and $7 billion of damage might be avoided yearly. Indeed, insurance companies have recently jumped on the ABS bandwagon, offering up to a 10 percent discount on ABS-equipped cars.

The consensus is that under almost all situations, ABS gives shorter stops and better control. The exceptions are sand, gravel, or freshly fallen snow. Locking the wheels may be

ANTILOCK BRAKES: PRICE AND PERFORMANCE

SYSYEM	AVAILABILITY	PRICE	MAXIMUM CYCLING FREQUENCY	PEDAL FEEL	IMPROVEMENT WITH ABS
DELCO MORAINE ABS VI	1991	$400	7 CPS	ISOLATION	5-20%
BENDIX ANTILOCK 6	1991	$750	10 CPS	ISOLATION	5-27%
BOSCH ABS 2U	1989	$800	10-15 CPS	PULSATION	NOT AVAILABLE

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MECHANICAL ABS: THE SMOOTH STOP

OPERATION

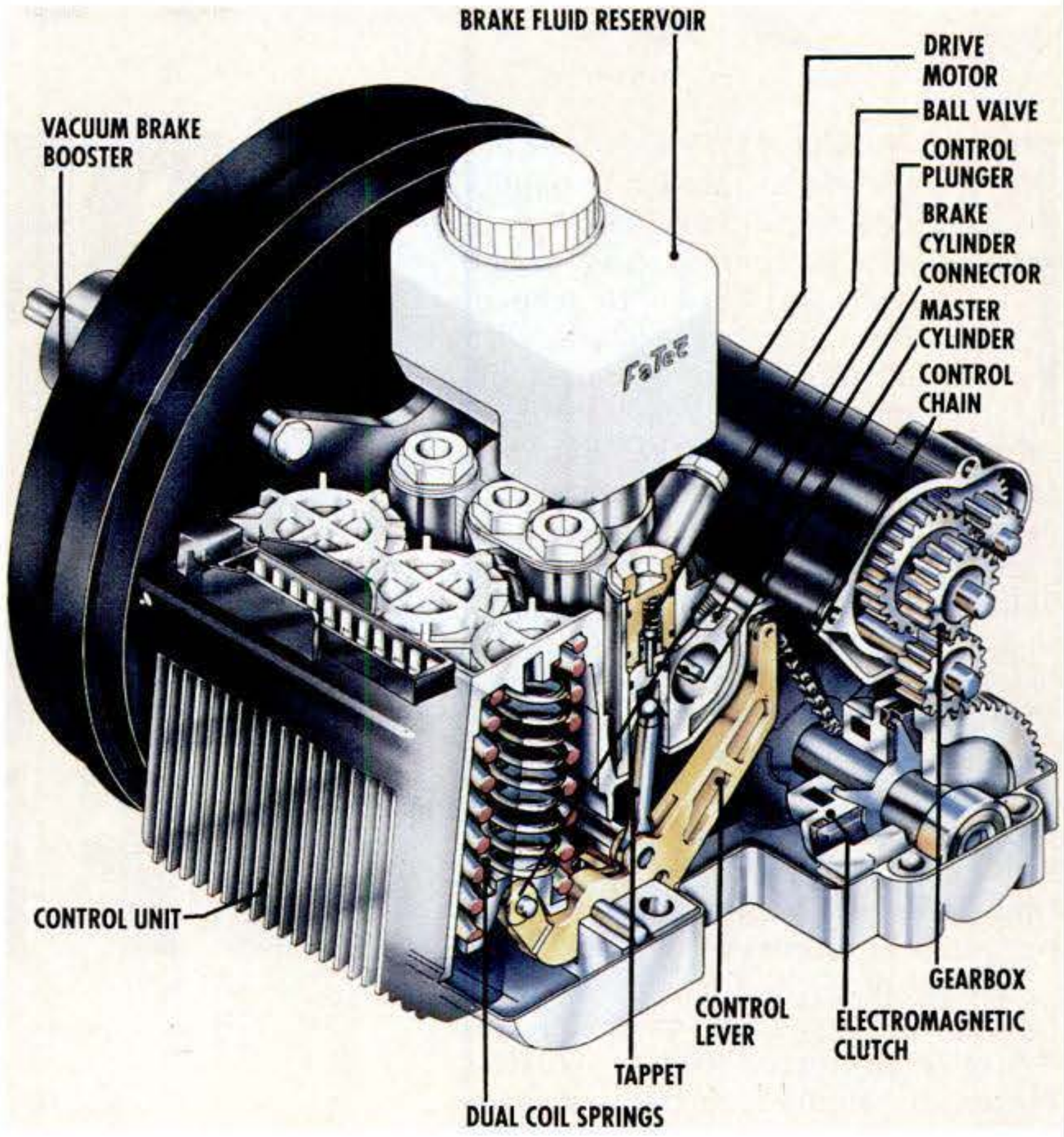
The FaTec C2 ABS modulator shown at right attaches to the car's standard vacuum brake booster and automatically adjusts brake pressure by moving a motor-driven plunger through a fluid chamber for each brake circuit. When the electronic control unit calls for antilock action, the electromagnetic clutch engages the motor to pull the control lever and plunger down. This gradually increases the volume below the plunger and reduces brake pressure. The lever arm also pushes a tappet to close an isolation ball valve, so the pedal remains firm and doesn't pulse. With restoration of wheel rotation, the clutch is allowed to slip, raising the lever arm and plunger under spring tension, which reapplies the brakes. In the illustration, each front wheel has one chamber and the rear wheels share one.

ADVANTAGES

Stepless analog ABS avoids the choppy feel of solenoid-based ABS.
Adaptable for either diagonal or front/rear brake split.
Can be used for traction control.
Coil springs store the energy needed to reapply brakes, eliminating the expensive hydraulic pump and accumulator.

DEVELOPMENT

A joint project of VDO—the European automotive instrument maker—and FAG Kugelfischer—the originator of the antilock brakes featured on the BMW K100 motorcycle.
FaTec C2 ABS was first used on Volkswagen's Futura concept shown at the Frankfurt auto show ["ANF," Jan.].—*David Scott*



better from this point of view, but with ABS you still have control.

The outlook for antilock brakes over the next couple of decades is a subject upon which normally sober engineers quickly turn to speculation. All feel that the next chapter in the evolving ABS story is to integrate it into a traction-control system ["High Rollers," Nov. '89]. By pulsing the brakes and controlling engine output, wheelspin can be all but eliminated while driving, extending the gains ABS has made in braking to the acceleration mode.

Ultimately, the more farsighted of those engineers I spoke with felt that ABS could be incorporated into a brake-by-wire arrangement, adding to the progress made by Bosch and BMW in their drive-by-wire systems on the BMW 750iL and 850i models. Michael Gatt, director of engineering for adaptive-braking and traction-control systems at Bendix, advises, "The system controlling the master cylinder would be similar, but much more sensitive to driver inputs. Eventually we see artificial intelligence assisting a brake-by-wire system. Imagine brakes that learn as they are used." PS

ABS WITHOUT THE JITTERS

Before test driving the new ABS VI system at the track, Delco Moraine let me try out a Japanese-market Honda Prelude with conventional antilock brakes as a basis of comparison. While traveling at 50 mph over wet pavement, I stood on the brake pedal. The Honda felt jittery as the modulation solenoids pulsed rapidly. I was able to control the car on simulated panic stops midway through a sharp turn. While attempting the same maneuver with the antilock brake system off, the car careened wildly out of control.

I then had an opportunity to test both the ABS VI and the Bendix Antilock 6 at each manufacturer's proving grounds. Under a variety of road conditions, stopping distances were markedly improved over non-assisted stops, as would be expected. More importantly, test data provided by each manufacturer make it clear that these systems perform on a par with more costly conventional antilock systems. In fact, Michael Gatt, director of engineering for adaptive-braking and traction-control systems at Bendix, says the driver would be hard pressed to tell the difference between Antilock 6 and 10. Performance and feel are identical.

Even with the left- and right-side tires on vastly different surfaces—a particularly troublesome situation brake engineers call "split mu" for the Greek symbol signifying the coefficient of friction—each system quickly brought the car to a controllable stop with minor steering input. As far as stability goes, I preferred Delco's piston-based system over the Bendix Antilock 6 for its ability to respond quickly to changes in road surface.

However, after the Delco Moraine ABS VI-equipped car comes to a stop, a curious thing happens: For an instant you can hear the motors whirring as the control pistons return to the upper position so that the car's base brake system is now in control.

The major difference separating these systems from each other and the more established antilock hardware is what the driver feels and hears when the systems are activated. Stopping with these systems is calm and undramatic. The only outward appearance that ABS was operating was the sawtooth motion of the car as the brakes grabbed and released.

But when it comes to isolating the brake pedal, many drivers—myself included—like the added information communicated through the pulsing pedal. In the final analysis, I prefer the pulsation to isolation.

This ability to brake safely on a slick surface at higher speeds may have an unintended side effect, warns Brian O'Neill, president of the Insurance Institute for Highway Safety: "Drivers can be lulled into overconfidence with ABS. In some instances, this could lead to a situation where the gains made by ABS will be partially offset by driver's traveling at higher speeds."—*B. N.*

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AUTO TECH '91

DETROIT SHIFTS THE BALANCE OF POWER

This year, the engine technology headlines are made in America.

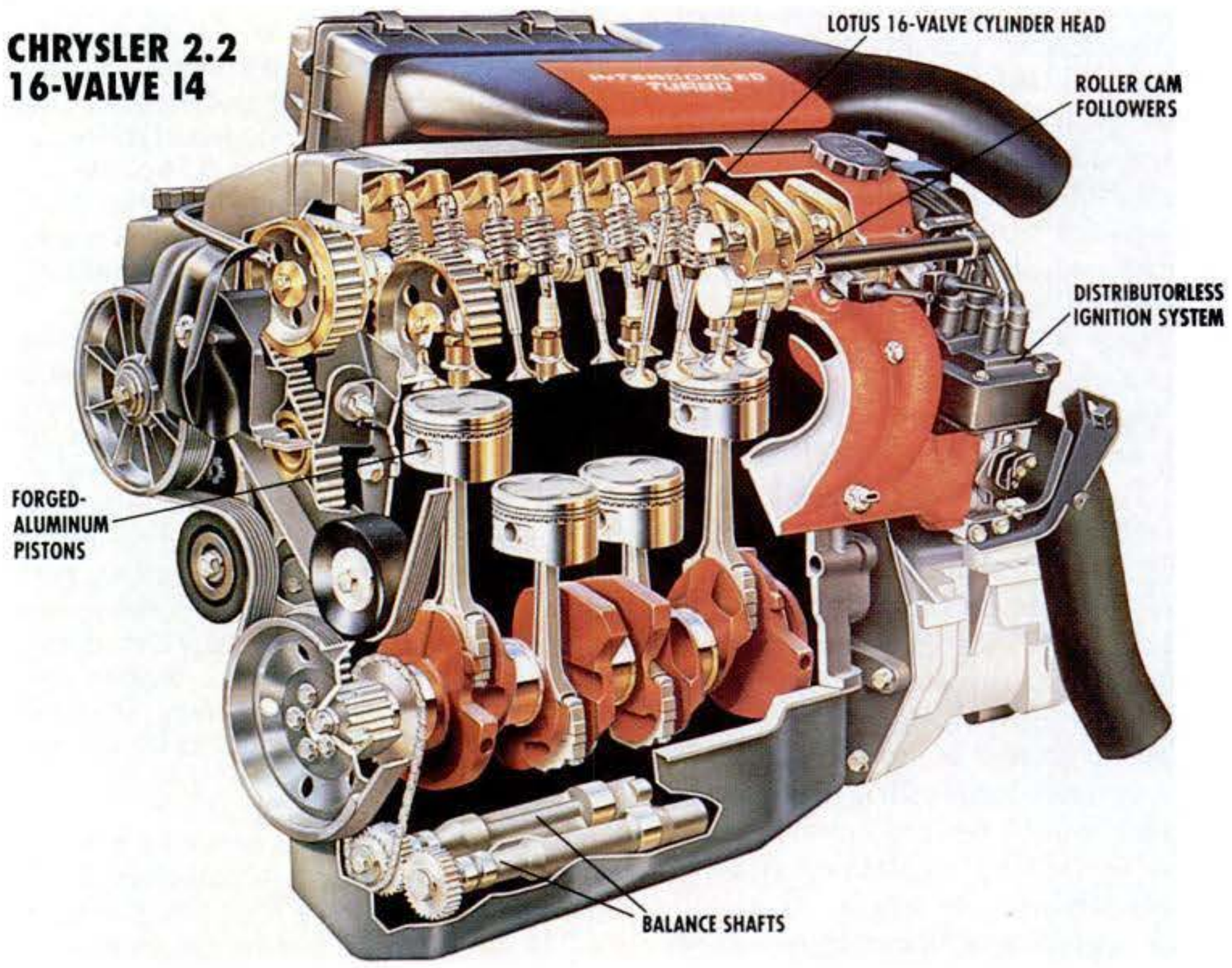
By DAN McCOSH and JIM McCRAW

Ford Motor Co.'s four-year billion-dollar mission to build a new world-class family of engines began during a test drive at Ford's Dearborn, Mich., proving grounds, with an inquiry from then-chairman Donald Petersen to senior engineer Jim Clarke. Petersen presented a challenge in the same sort of wide-ranging terms he had used earlier in directing styling chief Jack Telnack to scrap the boxy "Ford look" in designing the upcoming Taurus/ Sable sedans. Petersen wanted to know if Clarke and his engineers could design a replacement for Ford's decades-old V8 engines that would improve all aspects of performance, including emissions and mileage, and at the same time define the architecture of an entire range of future engines.

The result is the first high-volume, high-technology single-overhead-cam V8 ever produced in the United States. It required gutting a former Ford tractor plant in Romeo, Mich., retooling it for engine manufacturing, and retraining the tractor assembly workforce to build engines. The Ford single-overhead-cam V8 debuts in the 1991 Lincoln Town Car, replacing an engine originally introduced in the 1961 Fairlane and over the years developed into the present-day five-liter power plant.

Extensive engine development programs are going on outside of Dearborn too. General Motors has unveiled a powerhouse 24-valve V6 for '91; Chrysler teams with Lotus on a 2.2-liter 225-horsepower four-cylinder for its Dodge Spirit R/T. Another year into the future is GM's top-secret North Star V8, a 300-hp all-aluminum power plant destined for the 1992 Cadillac Allanté. More about those engines later; the biggest news is Ford's V8.

During the project's infancy, it was called the modular engine because it was designed to be the basis of a whole family of future engines—single- and double-overhead camshafts; two- and four-valves; iron and aluminum, and all-aluminum; front-drive or rear-drive—not because it snaps together like a Trans Former or Lego toy. It is, rather, modular in the sense that a sort of ideal combustion module has been created that can be made in all of the popular configurations, using similar bore spacings, bore-to-



For the '91 Dodge Spirit R/T, Chrysler's 2.2-liter four gets a 16-valve twin-cam Lotus cylinder head, a fixed-vane Garret turbocharger, and a whopping 225 hp at 6,000 rpm.

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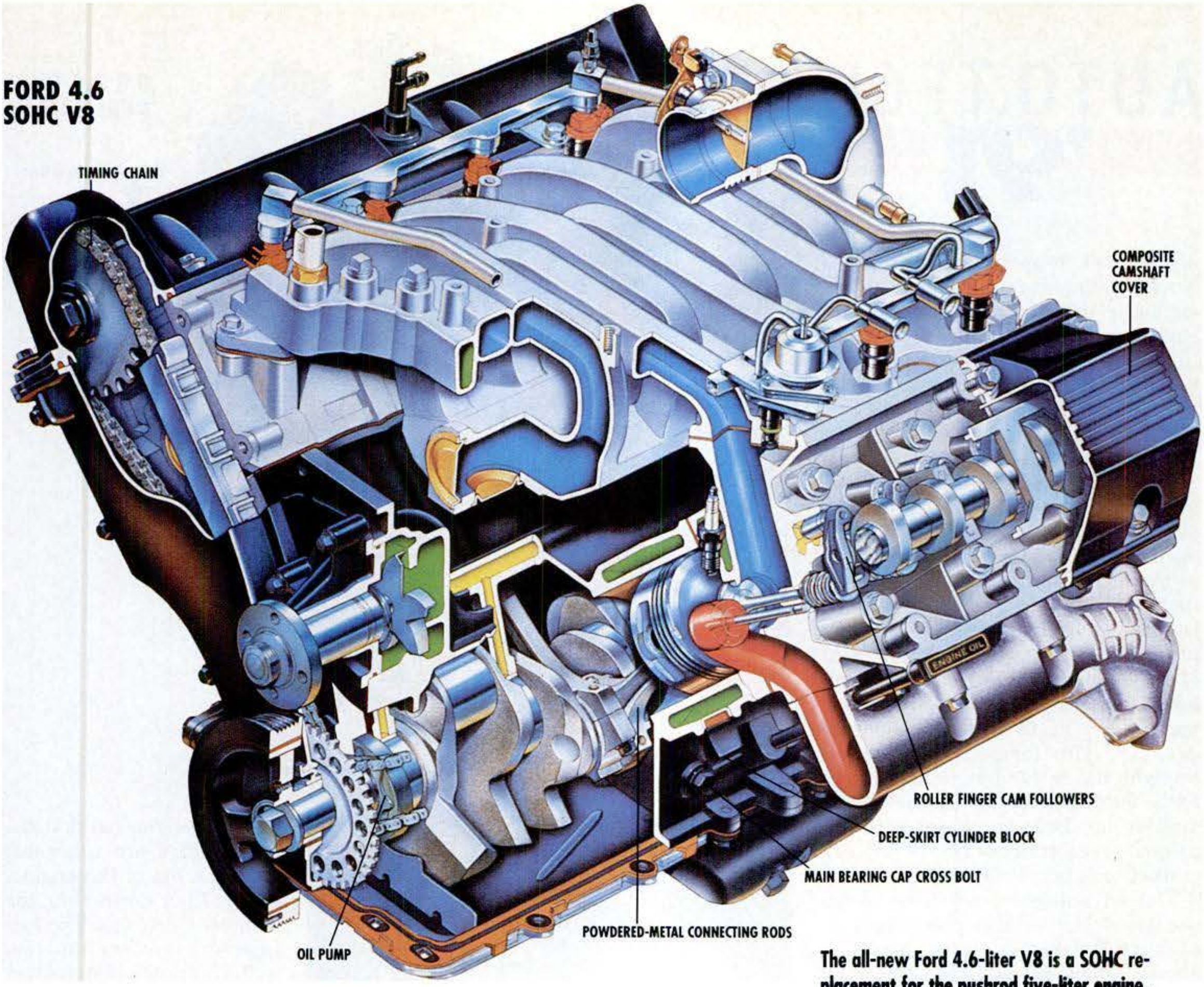

The all-new Ford 4.6-liter V8 is a SOHC replacement for the pushrod five-liter engine. The new engine family will expand in '92 to include a DOHC 32-valve offering.

stroke ratios, bolt patterns, valve trains, and induction system designs.

The first offspring of Ford's new engine family is a fascinating 190/210-hp (single/dual exhaust) torquer for the 1991 Lincoln Town Car that also will be used next year in the all-new Crown Victoria and Grand Marquis. Not exactly overwhelmed? Well, later variations are rumored to include a four-cam four-valve all-aluminum V8 headed first for the 1993 Lincoln Mark VIII, then reportedly for the Thunderbird and Mustang. A 300-hp output is the reported goal for this 32-valve version, which will use dual-mode intake tuning and a simplified variable-valve-timing scheme. Within a couple of years, we'll be driving more of its derivatives in smaller forms, including a 3.5-liter V8 and 60-degree V6 engines in 3.0-, 2.5-, and 2.0-liter sizes.

Ford's design goals with the new V8 included world-class performance in terms of horsepower output per liter. The team looked at Porsche, Mercedes-Benz, and Lexus V8 engines, and Alfa-Romeo and Honda V6s, among others, to study state-of-the-art technology. The studies pointed out a number of important basics to be incorporated in the new family of engines: stiff deep-skirt block construction with cross-bolted main-bearings caps; a short, stiff internally balanced crankshaft coupled with full-skirt pistons; and a microsmooth, ultra-straight, perfectly round piston bore. Because it is so critical to preserving piston ring seal and ensuring low exhaust emissions with minimal oil consumption, maintaining the accuracy of the cylinder bore became the reason behind many of the design decisions made by Clarke's engineering team. It's no coincidence that many of these virtues could also assist in keeping the engine clean running for 100,000 miles, the benchmark durability life span that future exhaust emission laws are expected to call for.

Starting with a cast-iron block dimensioned around a perfectly "square" bore-to-stroke ratio of 1:1 (a way of saying that the bore is 3.6 inches and the stroke is 3.6 inches), the major design considerations are geared for better power output and lower noise, vibration, and harshness. The block design accommodates a chain drive at the front for overhead camshafts, one per bank (for now). Chains were chosen for durability over all other considerations, with 100,000 miles as the bogey for chain life.

In another industry first, all engine accessories like power-steering pump, air-conditioning compressor, and alternator are mounted directly on the block. While this makes the block casting more complex, it eliminates heavy mounting brackets. Engine noise is lower too, because resonances originating at the brackets are gone and precise alignment of the various pulleys improves drive-belt life. The SOHC block is called a "dry valley" design because there is no camshaft in the valley between the cylinder banks, no lifters, and no oil being pumped about to lubricate the parts that aren't there.

The caps that hold the lower half of the main bearings are cross-bolted, with two bolts threaded into the block in the usual position (perpendicular to the pan rail) and two more bolts com-

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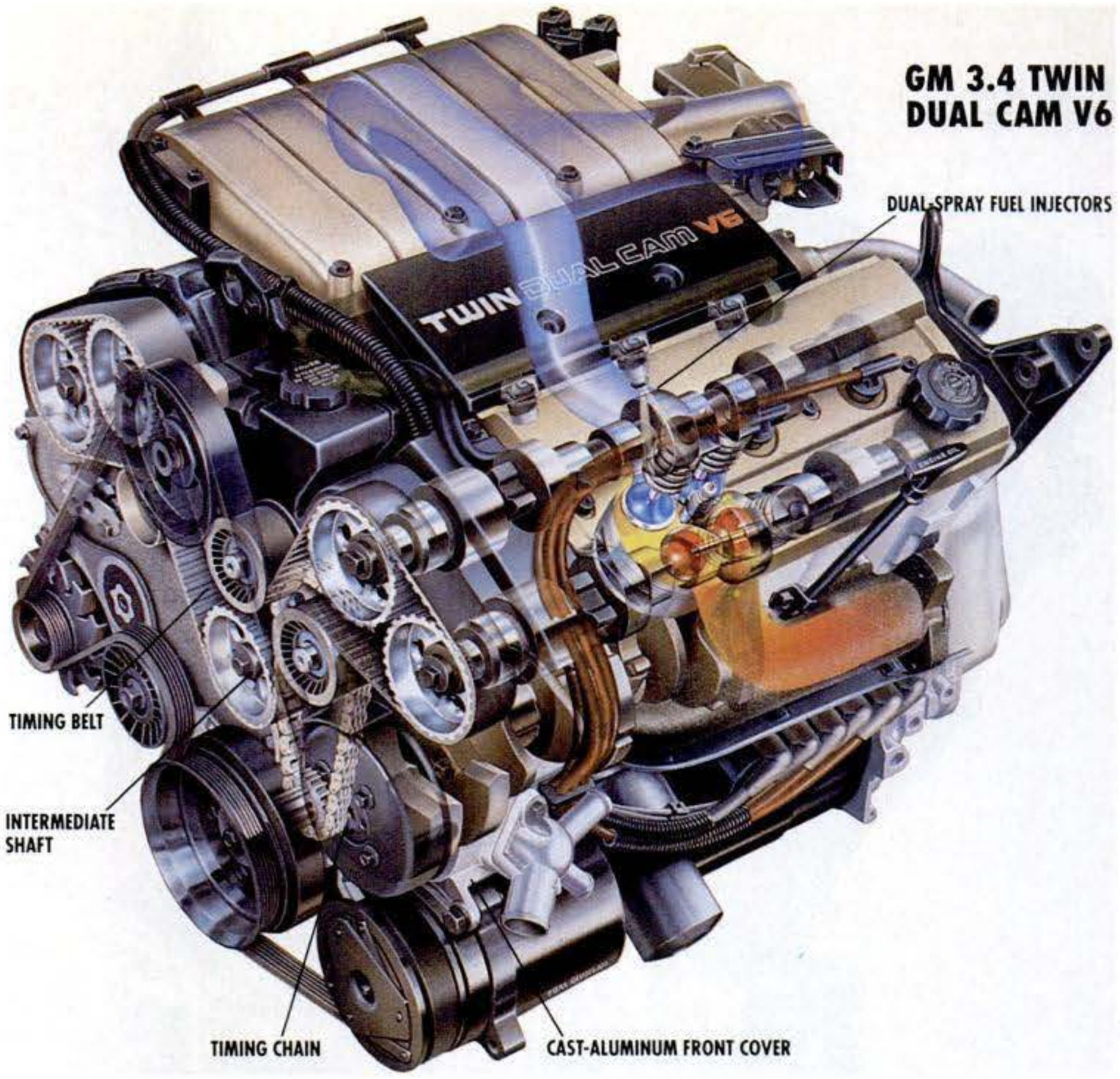
AUTO TECH '91

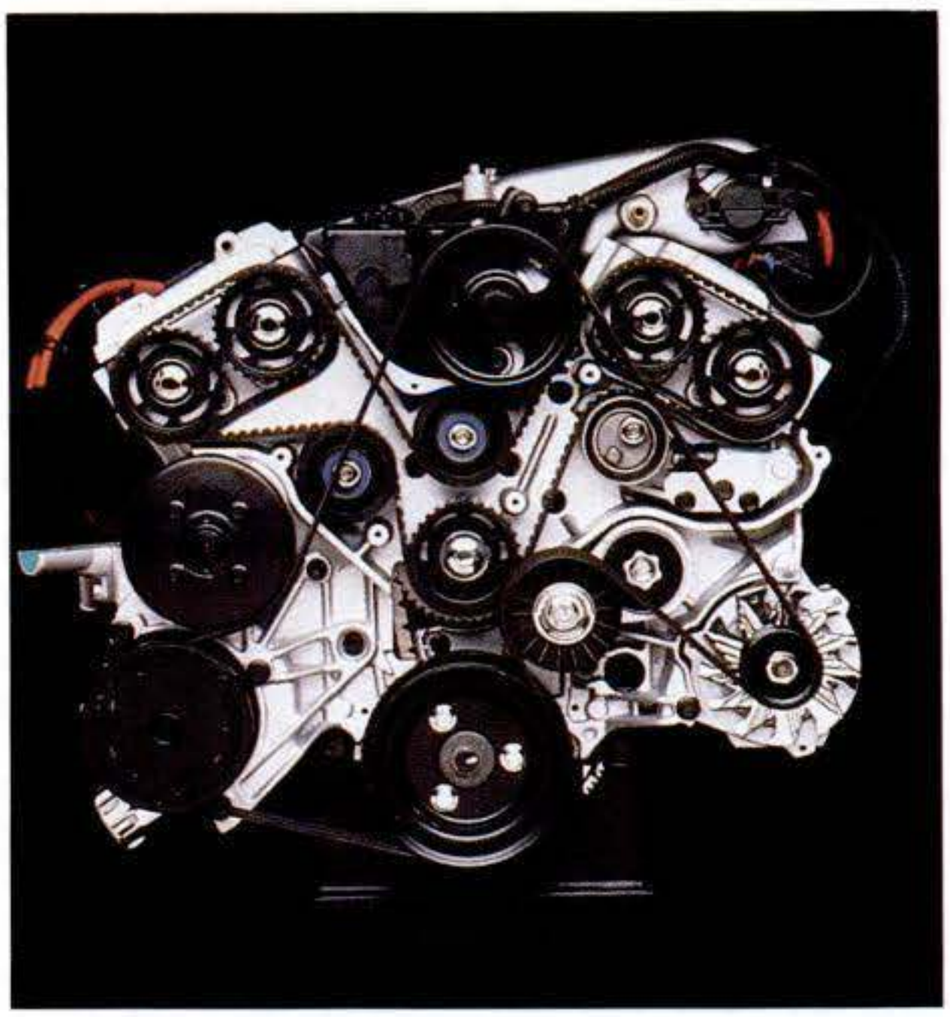
ing through from the outside of the block. An important difference in this engine is that the cross-bolts are installed in such a way as to equalize their pull on the cylinder bores, preventing distortion.

The connecting rods in the SOHC V8 engine are constructed by a technique known as powdered-metal manufacturing. Widely used in everything from postage meters to earth movers, this technology does away with the conventional pouring of molten metal into a mold. Instead, it begins with a high-pressure forming process (40 to 50 tons per square inch) of alloyed metal granules in a die, followed by a heat treatment in a sintering furnace at more than 2,000 degrees F. The formed rod is then brought up to red-hot temperatures for a forging step, finally yielding a durable finished component with appropriate alignment of the metal's crystalline grain structure.

The advantage of powdered-metal manufacturing lies in the ability to produce finished parts at "near-net shape"—meaning less machine work is required and material wastage is lowered. The process takes another curious twist too: The bearing cap, instead of being sawed off the completed rod, is deliberately cracked off across a built-in fault line in an "anvil" fixture. That means that when the rods are reassembled, the tiny hills and valleys of the metal structure will mate perfectly for all time, and the connecting rod bearing won't be tempted to move around once clamped to the proper torque.

The pistons are made of a high-silicon-content (16 percent) aluminum alloy and have more solid skirt area below the rings than usual to keep them square in the bores, and thus quiet. They are fitted with relatively narrow piston rings using little spring tension to keep them in contact with the cylinder wall, lowering friction losses by 15 percent. One objective was to eliminate as much total piston and ring friction as possible in the new engine family because low friction is equivalent to free horsepower, improving both fuel and oil economy. Engineers report oil usage at less than one quart in 8,000 miles. Reducing the oil content in exhaust gases is an important factor in extending a catalytic converter's useful life span to the 100,000-mile goal.





Twenty-four valves the hard way: The pushrod 2.8-liter GM V6 has been bored, stroked, belted, and fitted with four overhead camshafts. Above, the cam drive system.

The two overhead camshafts ride in aluminum carrier boxes, with the bottom half of each box cast into the head. The Ford design team evaluated all of the options and decided to use roller finger followers instead of having the cam lobes acting directly on bucket tappets. Zero lash is maintained by tiny hydraulic adjusters.

The cylinder heads for the SOHC V8 are designed so that the spark plugs are accessible from the top of the engine, rather than down near the exhaust manifolds. The fuel injectors are up top too, with their own distribution rail, shooting straight at the back of the intake valve.

The Ford distributorless ignition system uses two front-mounted coil banks regulated by the EEC-IV engine management system. Information to determine spark timing is fed to the management system by an electronic rpm counter at the crankshaft. This all-electronic ignition design helps fuel economy, saving the three hp normally lost in spinning a conventional distributor-type ignition at high rpm. Another power freebie is the absence of an emission-control air pump, good for another five free hp.

The net result in the Lincoln Town Car is a V8 engine that delivers more to the customer than the five-liter OHV V8: more horsepower per liter, and more absolute power; better fuel economy by 1.5 miles per gallon; greater acceleration, cutting 1.5 seconds from the Lincoln Town Car's 0-to-60-mph time. This was accomplished with a 20-pound weight saving over the five-liter.

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Far different from Ford's long-term program to create a new family of V6 and V8 engines is General Motors' plan for the new 3.4-liter twin dual-cam V6, which will be used initially in the 1991 Chevrolet Lumina, Pontiac Grand Prix, and Oldsmobile Cutlass Supreme. It offers buyers the chance to sample an output of 210-hp at 5,200 rpm and 215 pound-feet of torque at 4,000 rpm. That puts its performance up in the league of Ford's SHO Taurus engine, a 220 hp three-liter V6 built by Yamaha.

The engineers assigned to this project were not given a billion dollars, a clean sheet of paper, and a new plant. Instead, they had to make do with an existing engine (the GM 3.1-liter overhead-valve 60-degree V6, which grew up from the 2.8-liter introduced with the GM X-cars in 1980) and design a double-overhead-cam four-valve-per-cylinder package on a relatively modest budget. The project was headed up by Jay Subhedar of the Chevrolet-Pontiac-GM Canada group at GM's Tech Center in Warren, Mich., and started only three years ago. The group's mission was to increase the 3.1-liter engine's power by 50 percent. In terms of specific output (power per liter) the 3.4 makes about 62 hp per liter, about 35 percent higher than the new SOHC Ford engine.

For efficiency reasons, the engine would have to be built on the same assembly and machining lines as the regular 3.1-liter V6. While GM got its economies of scale this way, car buyers benefit too because many of the modifications made to the stouter DOHC block trickle down into the design of the 3.1.

The 3.4-liter DOHC is built around a 3.62-inch bore (0.12 inch wider than the 3.1-liter), while the 3.31-inch stroke is the same as the 3.1. The gray iron cylinder-block assembly uses only two-bolt main bearing caps on its four main bearings, and its entire lubrication system had to be changed radically to accommodate the special high-volume oiling needs of the 7,000-rpm DOHC design.

Because the 24-valve 3.4-liter is essentially an adaptation of an existing pushrod engine, the mechanics are rather complex. The aluminum cylinder heads are straightforward enough, using two intake and two exhaust valves in each pent-roof combustion chamber, with a centered spark plug as in the Quad 4 and the ZR-1 Corvette V8. The camshafts and hydraulic bucket tappets reside in a completely separate cast-aluminum cam carrier, two cams per carrier, one carrier per head.

The camshafts are driven by what is arguably the most complex drive system in the galaxy (see photo). First, a conventional timing chain runs from the crankshaft sprocket to an intermediate shaft, achieving the necessary 2:1 speed reduction. The intermediate shaft has a second sprocket mounted to its front, which uses a toothed rubber belt to drive all four cams. That intermediate shaft, of course, is a vestigial camshaft left over from the pushrod applications of this block design, and it could not be easily eliminated because it also drives the oil pump at the opposite end of the block.

A large computer-machined cast-aluminum front cover, which incorporates the water intake and pump, is bolted to the lower half of the front of the engine. All of the engine accessories are mounted directly to this cover. Counting everything, there are 16 sprockets or pulleys, on the front of the engine. All this hardware adds up, of course, making the 3.4-liter engine 120 pounds heavier than the pushrod 3.1-liter V6.

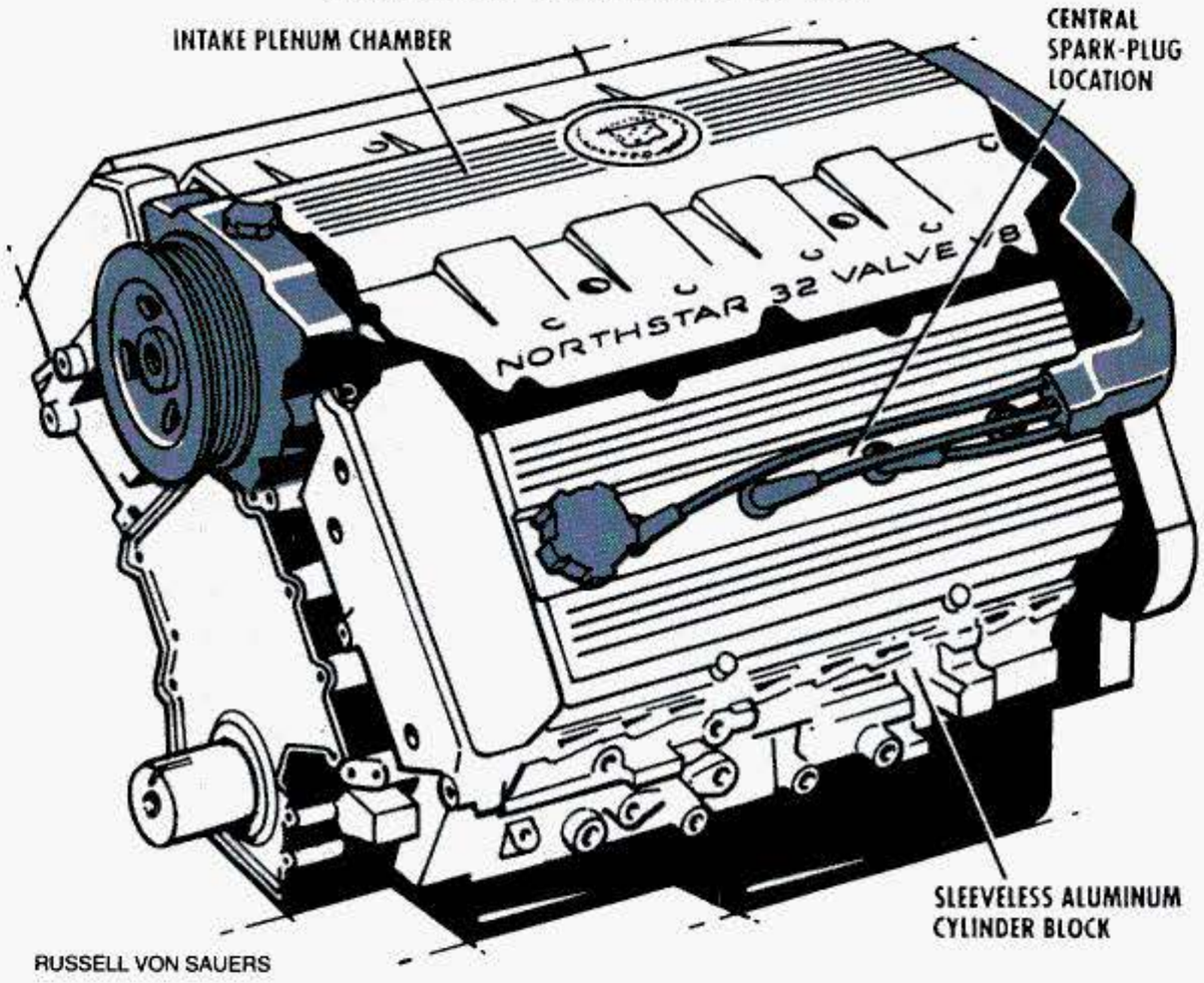
Subhedar calls the engine a free-spin design, which means that if a cam-drive element breaks at high rpm, a valve will not come into contact with a piston and destroy the engine. The 3.4 DOHC engine's compression ratio is 9.25:1, nearly half a point higher than the 3.1 engine's 8.8:1, improving power output.

The fuel system is AC Rochester multi-point electronic fuel injection, with dual-spray injectors to accommodate the two intake valves per cylinder. The injector nozzles each use a pair of five-degree-wide sprays, each aimed directly at the back of the intake valve it feeds.

While the new Ford engine and the 24-valve GM V6 clearly represent the biggest stretch for development engineers in 1991, they aren't the only contenders for headlines. Cadillac's North Star engine won't be publicly introduced for another year, but it seems certain that the 32-valve four-cam V8 will have a displacement of 4.6 liters and be rated at 300 hp. The engine block will be aluminum, as are present Cadillac engines, but with one big difference—no iron sleeves will be used to line the cylinder bores. Instead, it will be a silicon-alloy block, with the pistons riding directly on aluminum bore surfaces. This technology has been successfully used in Mercedes-Benz and Porsche V8 engines, of course, but its mass-production origins—in the Chevrolet Vega—shouldn't be overlooked. From all indications, GM will reserve this engine for installation in its most expensive models.

Despite their impressive specifications, all of these engines could be embarrassed by Chrysler's turbocharged 2.2-liter four-cylinder fitted to the Dodge Spirit R/T. The engine is rated at 225 hp at 6,000 rpm, with 210 lb.-ft. of torque at 4,800 rpm, thus exceeding 100 hp per liter. The power comes from a combination of a 16-valve Lotus-designed cylinder head and a conventional Garret TB03 turbo, which replaces the short-lived variable-vane turbo Chrysler pioneered just last year. The variable-vane concept, which uses a set of internal baffles to get a large-capacity turbocharger up to speed quickly, proved to be expensive. The R/T engine instead uses a small-displacement turbo to get quick response, although there is noticeable lag. The result is a high-revving, smooth-running four-cylinder that theoretically has the capability to run against most of the high-output V6s in current production. PS

CADILLAC NORTH STAR V8



RUSSELL VON SAUERS

Cadillac's 32-valve North Star V8 debuts in the '92 Allanté. All-aluminum construction and 300-hp, 300 lb.-ft. output are promised.

A ghastly, unwelcome effect—the notorious "red eye"—is the result of many flash picture-taking situations. Now there are ways to prevent it.

GETTING THE RED OUT

By ARTHUR FISHER

Are they children of hell? Visitors from Jupiter, planet of the Great Red Spot? Has something truly awful overtaken our nearest and dearest?

Nope. It's just red eye, plague of the flash snap-shooter.

Who has not taken a picture of a darling three-year-old at a party (or a darling 30-year-old for that matter), using the built-in flash of even a sophisticated 35mm camera, only to have the result ruined by the apparently demonic appearance of the subject, with eyes blood red? To respond "my child is not a vampire" doesn't really take the curse off such photos.

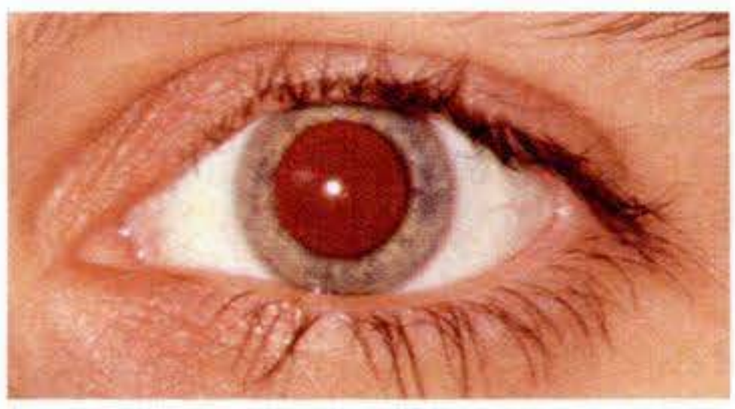
Now, however, some camera companies have recognized the problem, and devised new technologies to cope.

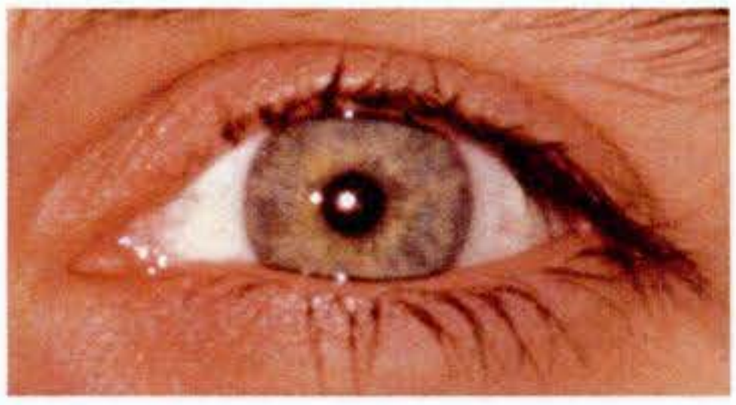
Why has it taken this long? Virtually all automatic cameras are made by Japanese photographic concerns. And, the representative of one of them told me "on background," the Japanese had only recently become concerned with the red-eye problem because they, like most Asians, have dark eyes, which are less prone to the phenomenon than light ones.

What causes the appearance of red eye in flash pictures? The standard explanation is most such photos are taken in a darkened environment, so that the subject's pupils are wide open, allowing light to reflect back from the blood-vessel-filled retina at the back of the eye. (The pupils dilate in the dark and close down in bright light.)

This is only partially correct. A noted New York ophthalmologist, Dr. Barry Belgorod, set me straight:

"When you shine a light straight into the pupil and view the eye so that the incoming beam and the reflected beam are superimposed, what you see is the general color of the interior, an orangy-brownish-reddish color. That's due to the pigments and the blood vessels of the structures behind the retina. The retina itself is transparent."





PHOTOS BY JOHN B. CARNETT

This pair of photos illustrates the effect of an anti-red-eye flash system. The top photo shows a typical red-eye result from a close-up flash photo. The bottom photo results with the new system.

One structure directly behind the retina is called the retinal pigmented epithelium, and, says Belgorod, depending on one's coloring, race, and skin type, there might be more or less pigmentation in it. The pigment is melanin. The overall color in red eye is a combination of the brown and black of the melanin and the red of the blood vessels.

As most readers will have noticed, red eye can appear even when the subject is not looking directly at the camera. The reason, says Belgorod, is that the interior of the eye is not like a plane mirror, but is spherical, so that light can bounce around. And some of it can emerge reasonably coincident with the incoming flash ray.

That is the reason some attempts to avoid red eye by flipping the flash unit above the camera body have been only partially successful.

The route taken by the three camera makers represented in these pages is more direct: close down the eye's iris and keep the pupil from being dilated before the flash picture is taken.

The Nikon and Canon cameras at right each illuminates the subject about a second before the main flash takes the exposure. With the Nikon Tele-Touch 300, the built-in flash fires first at one-third power, and 0.75 second later at full power as the shutter opens.

In the Canon Photura, a separate lamp in front of the reflector inside the flash head goes off, followed 1.25 seconds later by the main flash. (The flash unit of this camera is actually inside the lens cap.)

The idea in both models is to force the pupil to contract by lighting it, just before the actual flash goes off. In either case, the photographer can select the anti-red-eye mode or not.

The Auto S system used by Olympus, shared by both the Infinity Zoom 200 and the Infinity SuperZoom 330 (shown here), is more complex and uses multiple flashes (see box). The benefit claimed is smaller pupil size and less eyestrain for the subject.

Because of the great range of individual variability, it is unlikely that any of these systems will eliminate the problem completely. But they will certainly help bid bye-bye to photography's red-eyed monsters.

(At press time, Minolta introduced the Freedom Zoom 105i. It uses an anti-red-eye flash mode similar to the one on the Nikon and Canon cameras.) PS

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Getting the red eyes out is the mission of this trio of cameras: the Canon Photura, Olympus Infinity SuperZoom 330, and Nikon Tele-Touch 300.

HOW OLYMPUS COMBATS THE RED-EYE SYNDROME

BOB LANGE

Red eye results most often because flash pictures are made in a relatively dark room, so that the eye's pupil is wide open. The variable flash system of two Olympus models emits a burst of approximately 15 low-power flashes immediately before the main flash exposure and shutter release, as seen in the diagram, left. The diagram at the far left shows how this sequence results in a progressive closing of the pupil, thus preventing much light from entering the eye and bouncing back out again. The result is some reduction of the red-eye effect. As in other anti-red-eye systems, the pre-flashing is noticeable, but Olympus claims it is not annoying because the pre-flashes are dim.—*A. F.*

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All-wheel drive brings all-weather versatility to the Audi 200 Quattro (left) and dirt-road capability to the Mercedes-Benz 300TE (below).

PHOTOS BY JOHN B. CARNETT

Using sophisticated all-wheel-drive systems, these station wagons from Audi and Mercedes successfully combine utility with luxury.

By DON SHERMAN

4 WHEEL DRIVE WONDER

Copyrighted materia

WAGONS

AUDI 200 QUATTRO

MERCEDES-BENZ 300TE

Despite such creative alternatives as hatchback sedans, minivans, and utility vehicles, the classic station wagon is one automotive configuration that refuses to die. After years of faithful service hauling everything from Little Leaguers to nasturtiums—all the while maintaining the demeanor of an automobile, not a Peterbilt—the station wagon isn't about to relinquish its rightful spot in the archetypal suburban driveway.

That's fine by Audi and Mercedes-Benz, makers of the world's most expensive and sophisticated station wagons. Certainly the German automobile makers don't mind sending a few our way, packed to the gunwales with advanced technology. In fact, the Audi 200 Quattro wagon only comes equipped with anti-lock brakes and a full-time four-wheel drive. Mercedes' answer to Audi's ski machine is the 300TE with standard anti-lock brakes and an optional part-time all-wheel-drive system called 4Matic.

Using America's most popular station wagon, the Ford Taurus, as a yardstick, the German wagons are approximately the same size on the outside, somewhat smaller inside, and far more expensive. A loaded Taurus costs about $20,000, while the Audi 200 Quattro sells for $36,930 and the Mercedes-Benz 300TE 4Matic for $56,250. In return for those premium prices, the German wagons offer significantly more horsepower, better brakes, superior foul-weather traction, and lavish interior trimmings.

It's interesting that Audi and Mercedes-Benz meet in this four-wheel-drive wagon comparison because the two German auto makers are usually worlds apart when it comes to car design; Audi is primarily a front-drive maker while Mercedes-Benz favors rear-drive chassis layouts.

The two companies also follow distinctly different philosophies in engine and transmission design. The 200 Quattro is powered by a 2.2-liter five-cylinder in-line engine with a turbocharger and an air-to-air intercooler. The Audi's engine is rated at 162 horsepower at 5,500 rpm and 177 pound-feet of torque at 3,000 rpm. Instead of a turbocharger, Mercedes-Benz uses a three-liter six-cylinder engine to achieve similar output. The

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300TE's engine produces 177 hp at 5,700 rpm with a peak torque rating of 188 lb.-ft. at 4,400 rpm.

The Audi 200 Quattro is available only with a five-speed manual transmission, while the Mercedes-Benz 300TE is offered only with a four-speed automatic.

The two German brands also use entirely different drive-line designs to deliver torque to all four wheels. Housed within an extension of the Audi's transaxle is a unique worm-gear center differential. Normally, an all-wheel-drive center differential uses ordinary spur gears to split one input into two outputs; additional components are necessary to regulate exactly how much input goes into each output. The Audi design is different; called a Torsen (an acronym for TORque SENsing) differential, its worm gears parcel out the power with no need for extra limited-slip hardware.

While a pair of meshed spur gears will transmit torque equally well in either direction, worm gears work in only one: The driven gear cannot rotate the drive gear. In the case of the Audi 200 Quattro, this yields a torque split of 50 percent front/50 percent rear under normal conditions (no wheel slipping). In the worst case (lots of wheel slip), the Torsen differential will allot 78 percent of the torque to the front axle and 22 percent to the rear. This happens automatically, mechanically, and elegantly; the added weight over a comparable front-wheel-drive model is only 220 pounds. One other special feature of the Audi's drive line is an electrically locking rear differential. This is a get-unstuck device that the driver engages by a console-mounted switch.

The Quattro system is the result of Audi's 10 years of experience with permanently engaged four-wheel-drive systems. Mercedes' 4Matic system, on the other hand, is new to America for the 1990 model year. The engine, transmission, and rear-axle components are, for the most part, identical to rear-drive Mercedes 300TE models. 4Matic adds a transfer case, a drive line to the front wheels, and fairly elaborate electronic and hydraulic systems.

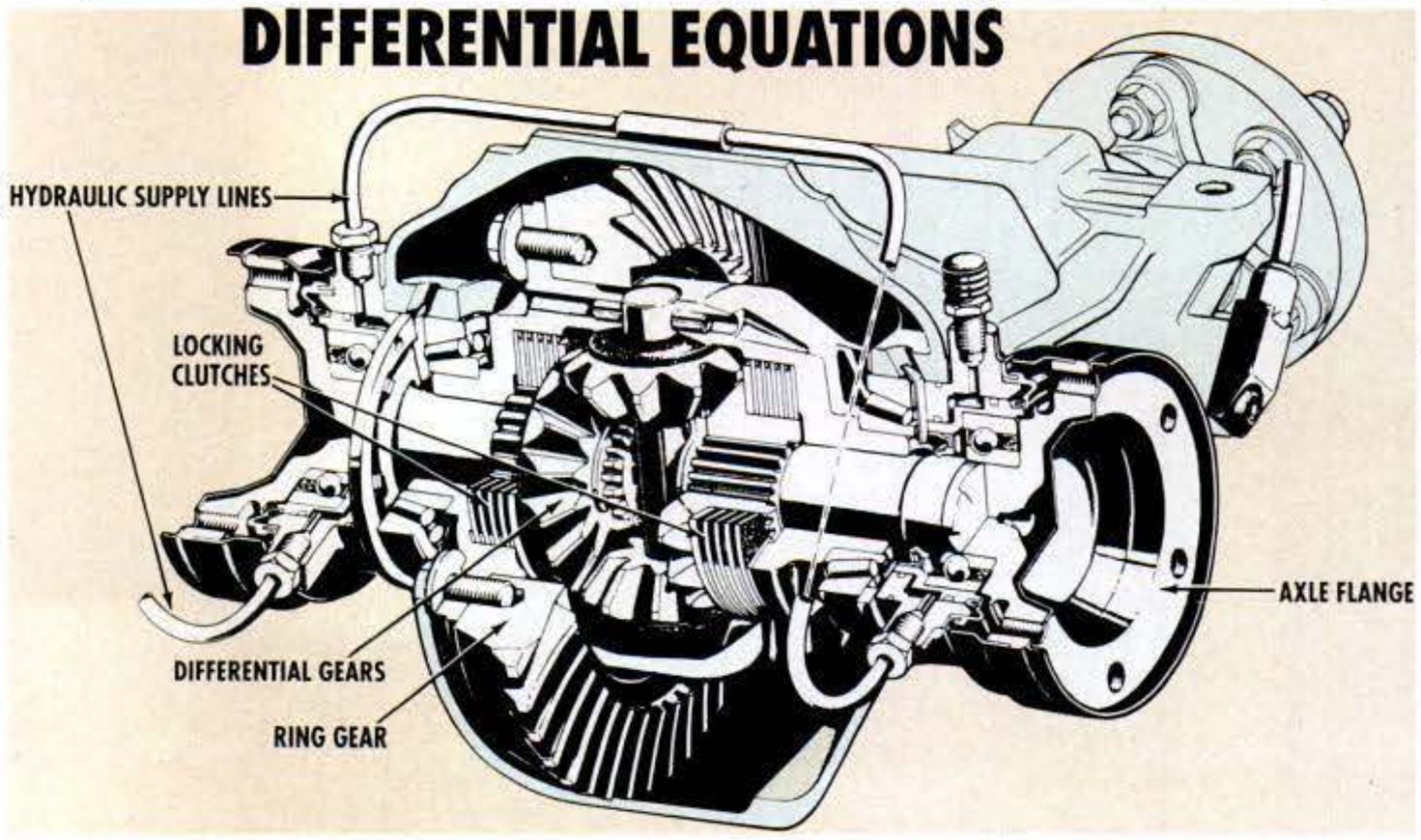
It's important to note that 4Matic engages all-wheel-drive on a part-time basis to preserve rear-drive handling characteristics during dry road conditions. It operates in four modes: regular rear-wheel drive; four-wheel drive with 35 percent of the torque delivered to the front axle; four-wheel drive with a locked center differential (50:50 torque split); and four-wheel drive with both the center and the rear differentials locked.

The heart of the 4Matic system is a transfer case flanged to the rear of the 300TE's automatic transmission. Within this aluminum housing are a planetary-type center differential (see box), a hydraulically actuated multi-plate clutch (to lock the differential), and a second multi-plate clutch that controls the engagement of front-wheel drive. A front differential is mounted to the engine's oil pan.

4Matic's brain is a control computer that monitors wheel speeds (sharing sensors with the ABS system), steering-wheel angle, and brake actuation. Muscle is provided by a hydraulic system: an engine-driven pump, a pressure reservoir, and fluid lines to three drive-line clutches. When the control computer signals a mode change, stored hydraulic pressure quickly activates the appropriate clutch.

Below 12 mph, 4Matic always engages to assist in starting the car from rest. During any brake application, four-wheel drive is always disengaged and the differentials automatically unlock. During certain cornering conditions, front-wheel drive is engaged to enhance stability. If wheel slip is detected (indicated by unequal wheel speeds), 4Matic first engages front-wheel drive. If slippage persists, the center differential is locked, altering the front: rear torque split from 35:65 to 50:50. The next step is to lock the

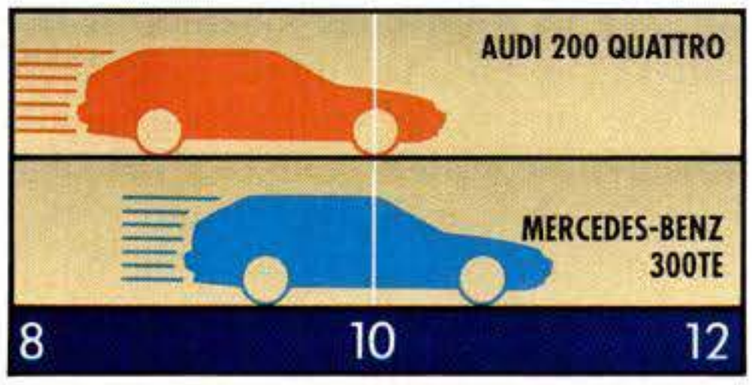
DIFFERENTIAL EQUATIONS



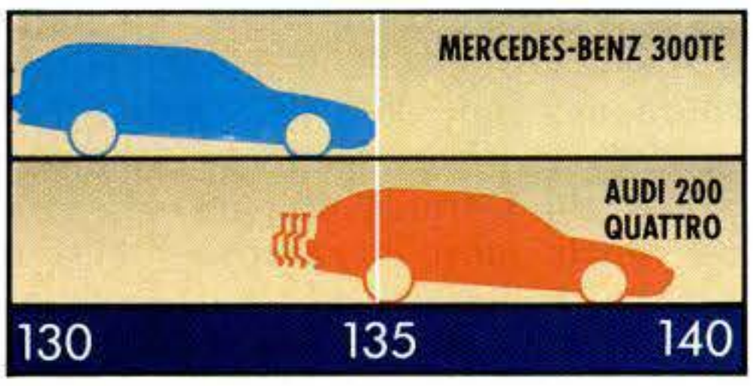
In simplest form, a differential gear set allows each wheel of a drive axle to seek its own speed when making a turn. Unfortunately, that virtue is what sets tires spinning on a slippery surface, as power is transferred to the wheel with the least traction.

The Mercedes-Benz locking rear differentials will solidly link together the rotation of left and right wheels to overcome this condition. The system shown (as used on the 300TE 4Matic) uses hydraulically actuated clutch packs on either side of the ring gear to attain 100 percent locking for sure starts on slick surfaces. Engagement is dictated when readings from the ABS wheel speed sensors indicate excessive wheelspin; the clutches automatically disengage above 19 mph, when coasting or when the brakes are engaged, thus preventing the loss of directional stability.—*Norman S. Mayersohn*

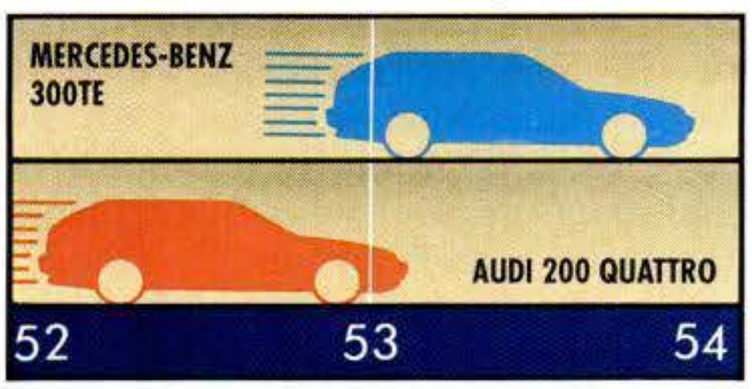
ACCELERATION 0–60 mph (sec.)



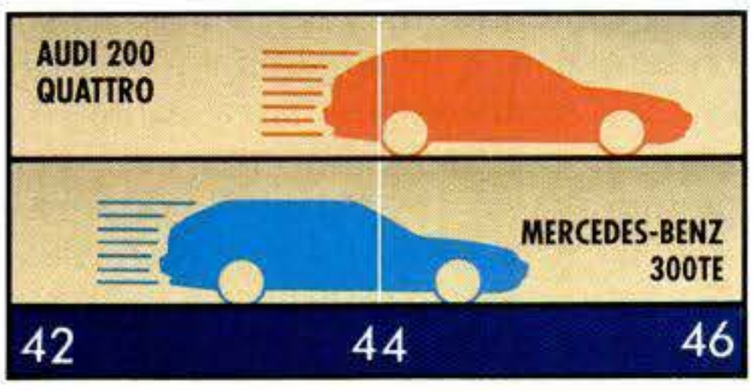
BRAKING 60–0 mph (ft.)



DOUBLE-LANE CHANGE (mph)



SLALOM (mph)



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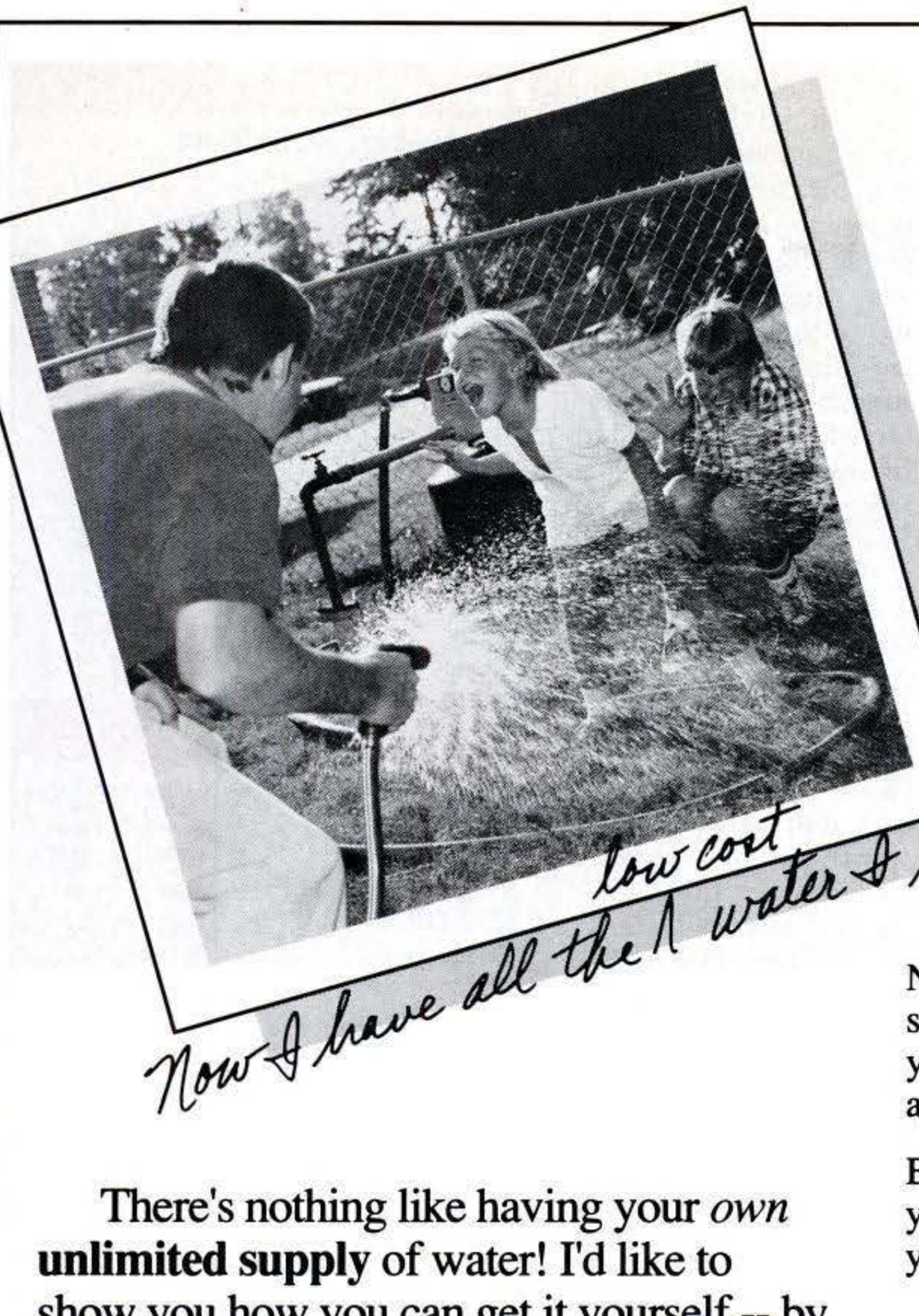

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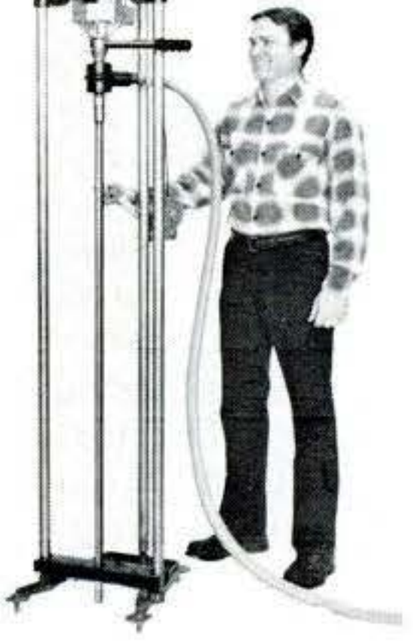

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rear differential. The 4Matic control computer has a learning capability, so tire wear and tire-pressure variations don't confuse it. 4Matic costs an extra $6,600 and adds 275 pounds to the Mercedes-Benz 300TE.

Despite the fact that the Audi casts a substantially larger shadow than the 300TE (2.9 inches more width, 4.5 inches more length), it's lighter by 280 pounds. The 200 Quattro is also 4.3 inches lower overall, and its rear hatch is tipped rakishly forward, so it suffers in a cargo-volume comparison. The Mercedes is rated at 42 cubic feet, while the Audi packs only 37 cubic feet (the reference Taurus wagon has a 46-cubic-foot cargo hold). In both wagons, the rear seat can be sacrificed to haul gardening supplies, sports gear, or antique funiture booties. In the Audi, the split rear seat backs fold forward. In the Mercedes, the seat bottom must be lifted up before the backrest can be flattened. Both wagons offer under-floor storage in the cargo compartment. Mercedes provides a full-size spare wheel and tire beneath the floor while the Audi gets by with a high-pressure mini-spare stowed in a sidewall compartment.

Even with less power under the hood, the Audi boasts the superior power-to-weight ratio, so it wins both 0-to-30-mph and 0-to-60-mph contests. The Mercedes 300TE feels particularly sluggish off the mark, and it also misses the 10-second 0-to-60 hurdle by a full second. The Benz does make amends in passing tests, though, because its automatic transmission is able to select just the right ratio for the conditions.

On the skid pad, the Audi demonstrated better grip (0.76 g versus the Mercedes' 0.73 g). The other handling test results held true to expectations: The Audi edged the Mercedes with a slight margin in the slalom (helped by a slightly shorter wheelbase), while the Benz proved a bit better in the double-lane-change maneuver (thanks to a firmer suspension). Throughout the handling tests, we observed no particular behavior—either positive or negative in nature—that could be attributed to the four-wheel drive lines.

Neither the Mercedes nor the Audi wagon is rated for severe off-road use (due to a lack of open-tread tires, extra ground clearance, and drive-line guards), but they do dig in and keep rolling over bad roads and during adverse weather conditions. At a California mountain site we made excellent use of a fresh snowfall—the white powder was knee-deep, covering a rutted path around a reservoir. Stopping and starting, tight maneuvers, and hard charging over the snowy circuit posed no problems for either the Audi or the Benz. Each was as sure-footed as Santa's reindeer on Christmas Eve.

When driven into a snowy curve with abandon, the Audi will slide wide in a nose-first attitude. The Mercedes will step out in a classic four-wheel drift, though, as long as you hold the throttle down. This we attribute to each wagon's weight distribution and torque-splitting strategies.

Either car will get you to your ski chalet in style. The Audi 200 Quattro is the more progressive design—sleekly styled, tastefully decorated, and mechanically elegant. It also represents the superior value: Except for hauling bulky cargo, it will do everything the Mercedes can do at two-thirds the price. The Mercedes 300TE is conservatively styled, well appointed, and engineered to a fare-thee-well, but none of those virtues will get you over the mountain any better than the Audi 200 Quattro can. PS

ELECTRONICS VS. MECHANICS

Balancing traction and torque is the job of a four-wheel-drive system, whether mechanical or electronic. In pursuit of this goal, a number of systems, ranging from clever to complicated, have been introduced in recent years. Each scheme works to overcome the natural tendency of a differential to allow the wheel with superior traction to stop when it finds traction and transfer all power to the wheel at the opposite end of the axle.

Chief advocate of the all-mechanical approach is Audi, which uses a Torsen differential to split torque effectively—and, more important, instantly—between front and rear axles to retain power at the wheels with traction.

In contrast, Mercedes has developed one of the more complex electronic approaches, using wheelspin sensors to signal hydraulic clutches that engage virtually any combination of wheels as necessary. It is a fascinating concept, in theory, providing the ultimate in flexibility and response. Unfortunately, it depends on wheel slip to activate the sensors, so it requires some time to compute and respond. To me, the time lag is noticeable and aggravating, kicking four-wheel drive in and out in the midst of cornering in snow, too late to do anything but upset the feel of the car.

On the other hand, the Audi is solidly balanced—responsive and direct in the dry as well as on snow and ice. Its attitude remains under the driver's control rather than being second-guessed by the computer. In this contest between a well-developed mechanical system and state-of-the-art electronics, the Audi wins with all four wheels on the ground.—*Dan McCosh*

POPULAR SCIENCE TEST RESULTS

	Mercedes-Benz 300TE 4Matic	Audi 200 Quattro
ACCELERATION and HANDLING		
0-30 mph (sec.)	3.3	4.1
0-60 mph (sec.)	10.4	11.0
30-50 mph (sec.)	15.2	5.2
50-70 mph (sec.)	11.8	7.2
Double-lane change (mph)	53.1	53.9
Slalom (mph)	45.7	44.8
Road holding (g)	0.76	0.73
BRAKES		
60-0 mph cold (ft.)	141	134
60-0 mph warm (ft.)	139	135
60-0 mph hot (ft.)	143	136
INTERIOR NOISE		
Idle (dBA)	49	45
60 mph (dBA)	70	68
Acceleration	77	75
SPECIFICATIONS		
Engine	2.2L I5	3.0L I6
Valve train	SOHC 2 valves/ cylinder	SOHC 2 valves/ cylinder
Power at engine speed (hp @ rpm)	162 @ 5,500	177 @ 5,700
Torque at engine speed (lb.-ft. @ rpm)	177 @ 3,000	188 @ 4,400
Compression ratio	8.4:1	9.2:1
Transmission	5-speed manual	4-speed automatic
Final drive ratio	3.89:1	3.29:1
CHASSIS		
Front suspension	Independent, strut, coil spring, anti-roll bar	Independent, strut, coil spring, lower control arm, anti-roll bar
Rear suspension	Independent, control arm, coil spring	Independent, multi-link, coil spring, anti-roll bar
Steering gear	Rack-and-pinion	Recirculating ball
Turning circle (ft.)	34.2	36.7
Brakes	Disc, disc ABS	Disc, disc ABS
EPA MILEAGE		
City	17	16
Highway	24	20
DIMENSIONS		
Wheelbase (in.)	105.9	110.2
Length (in.)	192.7	188.2
Width (in.)	71.4	68.5
Height (in.)	55.9	60.2
Curb weight (lbs.)/distribution (% front: rear)	3,580/ 58:42	3,860/ 52:48
Fuel tank (gal.)	20.6	19.0
Interior volume (cu. ft.)	95	94
Cargo volume (cu. ft.)	37	42
PRICES, PARTS, and SERVICE		
Base price	$36,930	$56,250
Price as tested	$37,865	$56,685
Major options (over $100)	Pearlescent metallic paint $450; California equipment $150	Partition net and luggage cover $435
SPARE-PARTS COST		
Brake pads, front	$125	$ 67
Brake pads, rear	85	30
Front shock/strut insert (each)	110	201
Front fender	228	173
Alternator	394	769
Fuel pump	231	242 each (2 pumps)
Ignition module	155	707
Grille	100	156
Front bumper	308	529
Windshield	463	282
Taillight lens	94	64
PS SERVICEABILITY		
Total of 12 (maximum of 60 points) items	39	44
Best feature	Fuse access	Fuse access
Worst feature	Spark-plug access	Spark-plug access

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Garbage [Continued from page 63]

what goes into landfills," adds Norm Crampton, executive director of the Indiana Institute on Recycling in Terre Haute. "Try cutting the grass high and letting it lie. In the fall, mulch leaves and spread them over the yard. This adds nutrients and conserves moisture." Many states are banning yard waste from curbside collection ["Home Newsfront," July].

Zoo Doo?

Seattle's waste-management plan is often held up as a model for reducing trash. Although its program is voluntary, at 78 percent the city has one of the highest recycling-participation rates in the nation. Fully 44 percent of the residential waste stream is diverted for recycling. As a result, Seattle scrapped plans for a waste-to-energy plant.

"As the price increases, people generate less," explains Jennifer Bagby, an economist for Seattle's solid-waste utility. Since 1981, residents who throw out more trash have paid for it accordingly. Stronger enforcement was added last year, along with curbside collection of recyclables and a yard-waste ban. The plan is near all-encompassing: A pilot program recycles latex paint. Even the zoo sells animal-generated fertilizer called Zoo Doo.

Most agree that the technology to solve the garbage problem is here and the economics is coming, but obstacles still remain. "Our problems are not technical," notes Ruckelshaus of Browning-Ferris Industries. "We can operate a system that would satisfy even the most ardent environmentalist and still allow us to make money. No, our problem is political."

With increased public education, the image problem of waste facilities could be overcome, adds Ruckelshaus. "Informing the public of all the risks, how you intend to control them, and the benefits of the project, is the only formula that stands a chance of success," he says. "A landfill is not a rose garden, but neither is a tire factory or a steel mill, and towns fight to get those."

Rathje agrees, but says we should not let up: "The attention span of the American public and media is relatively short. I'm worried that we're going to get to the point where garbage is no longer sexy enough to write big articles about and that the major problem will not have gone away."

Incidentally, what happens to the trash collected by Rathje and others of The Garbage Project? "After we sort it, we save some samples for analysis, but it mostly gets thrown out," he says. After all, it is garbage. PS

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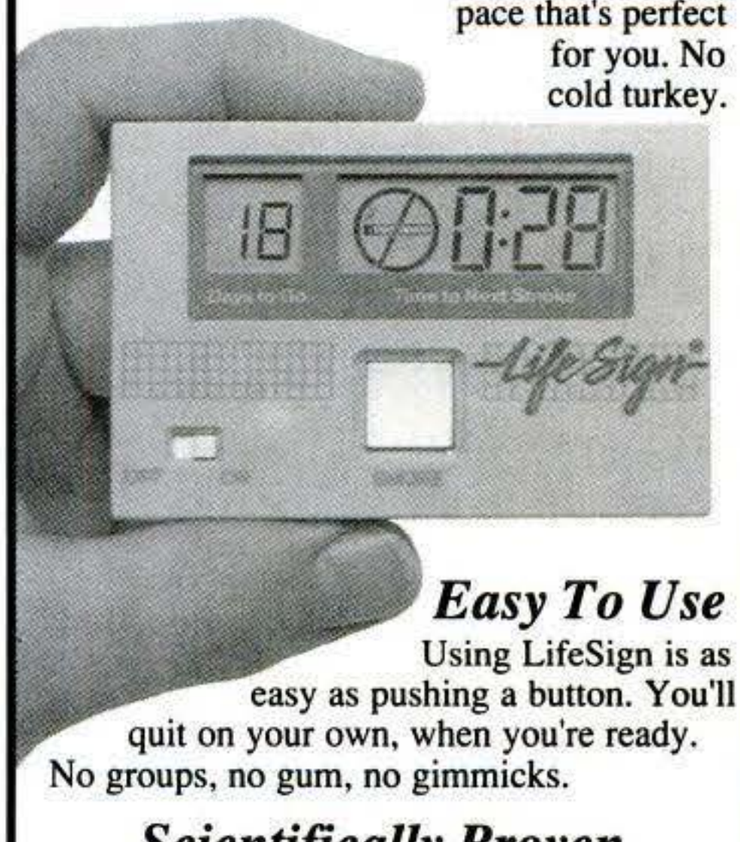

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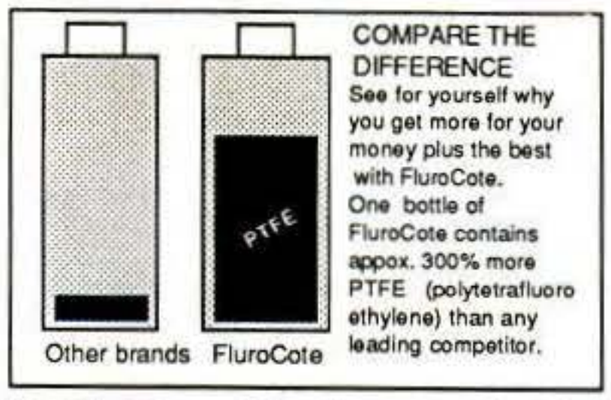

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Earth-orbiting balloon

[*Continued from page 71*]

landing area with the assistance of its GPS receivers, which indicate the balloon's true location to within 10 meters.

By opening a valve and deploying a rip panel that tears its inner lining, they will deflate the anchor balloon. Next the crew will bleed gas from a valve atop the helium envelope until the balloon begins to descend; a pair of radar altimeters provide them with accurate readings of distance to the ground. As the balloon sinks closer to Earth, the three will don helmets and heavy clothing to blunt the impact of a possibly hard landing. With only plastic and foam materials used in the interior of the capsule, there is no worry about falling onto sharp metal edges.

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If *Earthwinds* is drifting at a high speed when it touches the ground, the captain will push a button triggering a detonator that severs the helium balloon from the capsule. As a safety measure, the destruct device is connected to its deployment button with a newly developed fiber-optic laser link that's immune to a potentially catastrophic accidental activation that could be caused by radio or electrical interference during the voyage. With the now-unfettered helium envelope heading quickly heavenward, a single metal cable still connecting it to the capsule will rip a sizable hole in its plastic skin. Once its big helium bubble escapes, the envelope will be transformed into an evanescent sheath of polyethylene fluttering to the ground nearby.

It's easy to imagine the trio of adventurers—anxious to stretch limbs cooped up for far too long—unbattening the capsule's hatches and clambering somewhat stiffly back onto terra firma. At the moment of completing a historic flight, it is customary for balloonists to kiss the ground and drink champagne. A crew that had just gone around the world might reasonably be expected to require more than one bottle. PS

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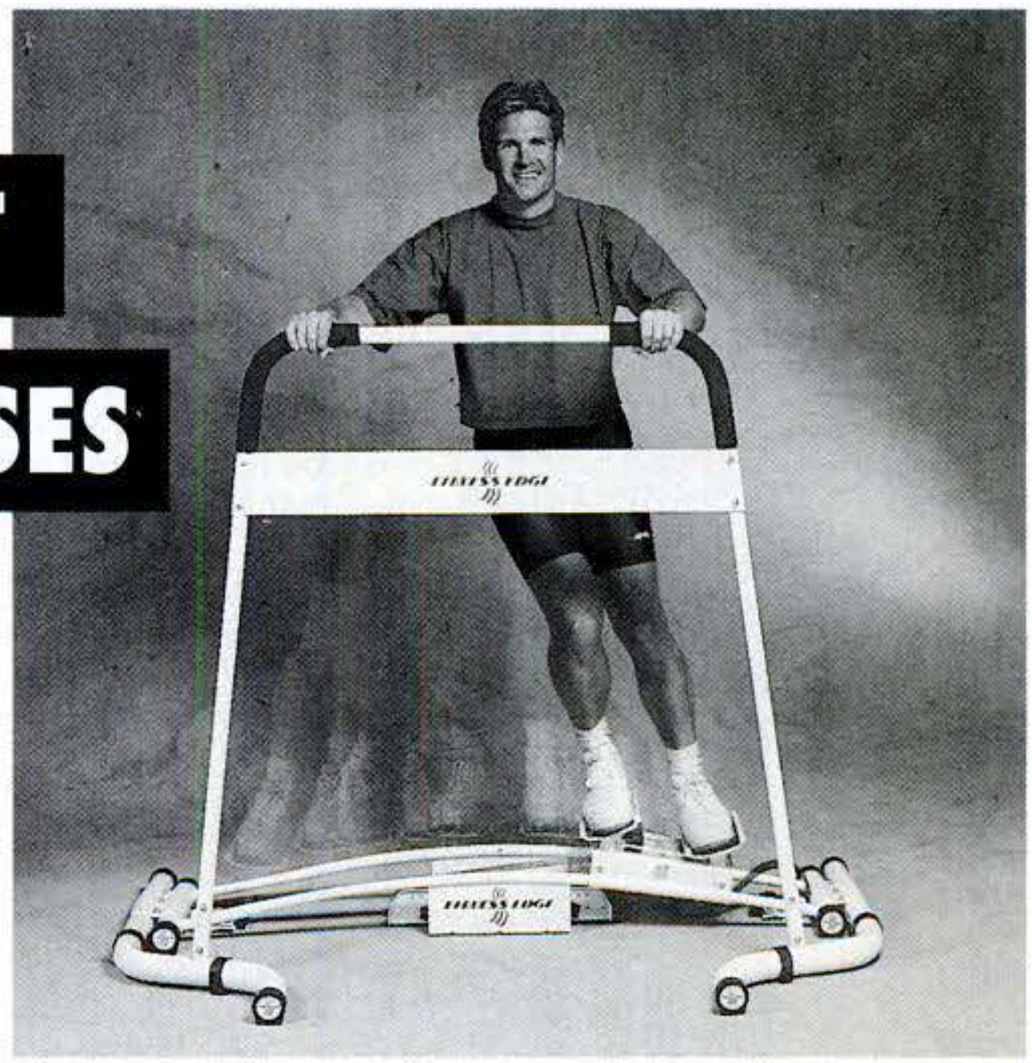

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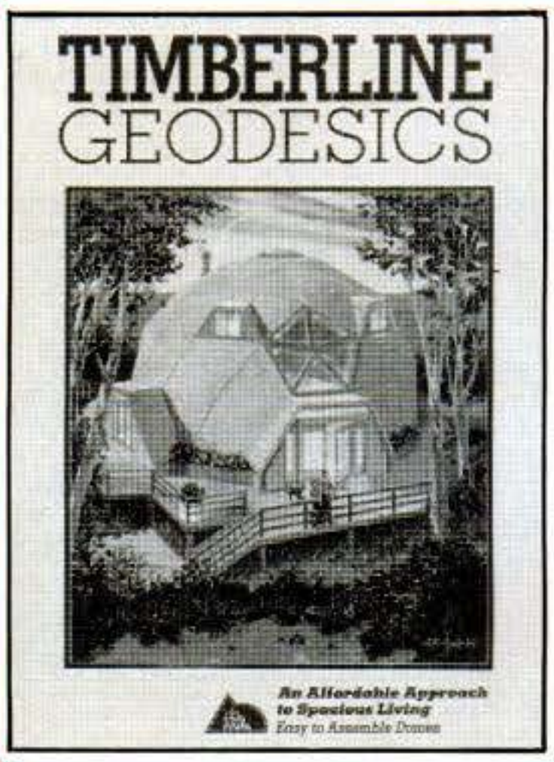

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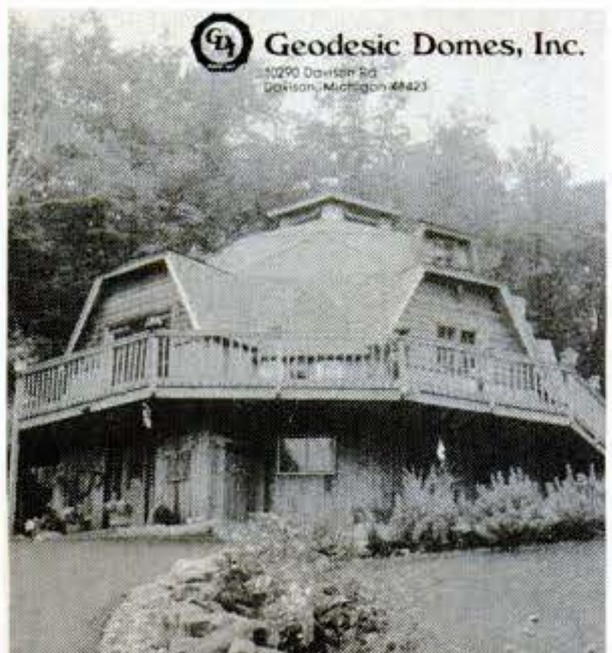

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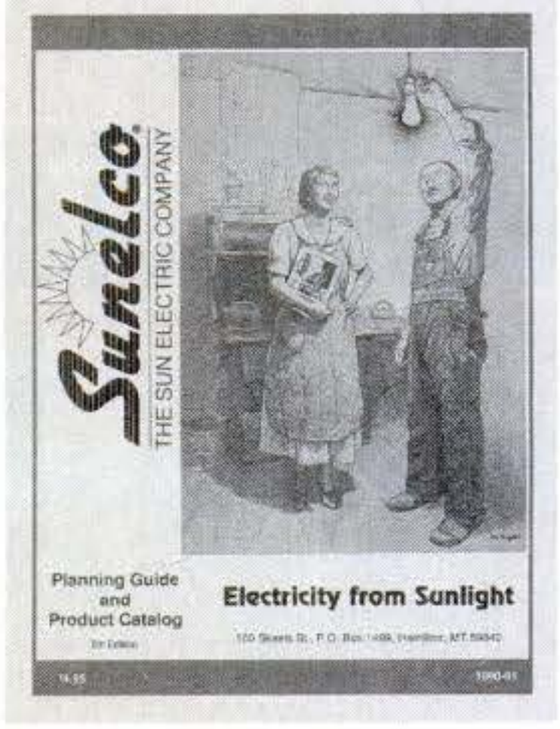

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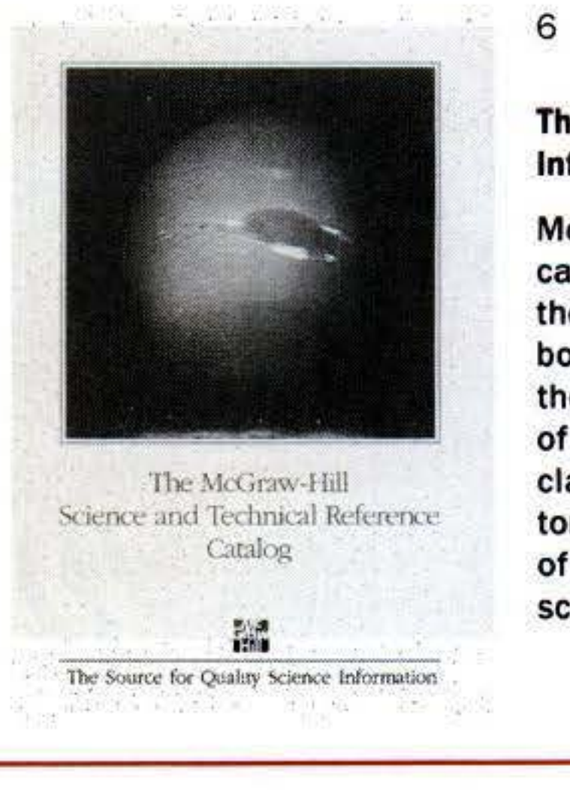

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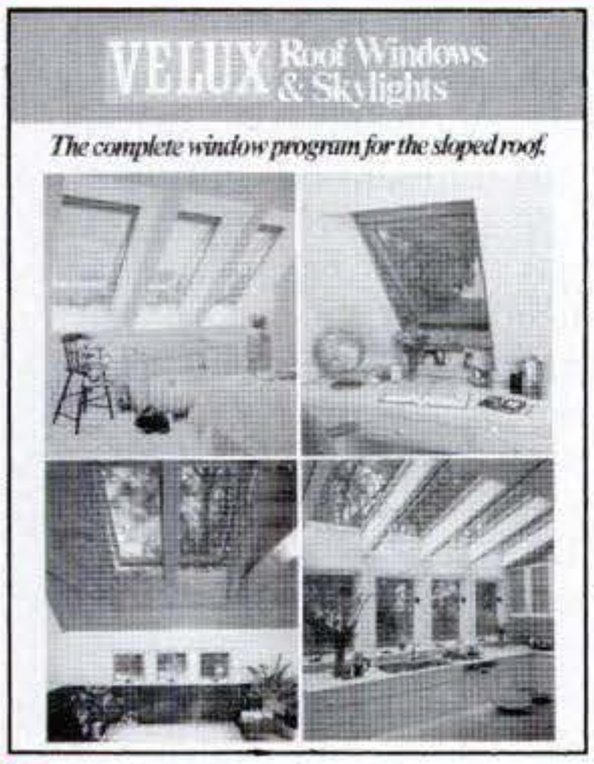

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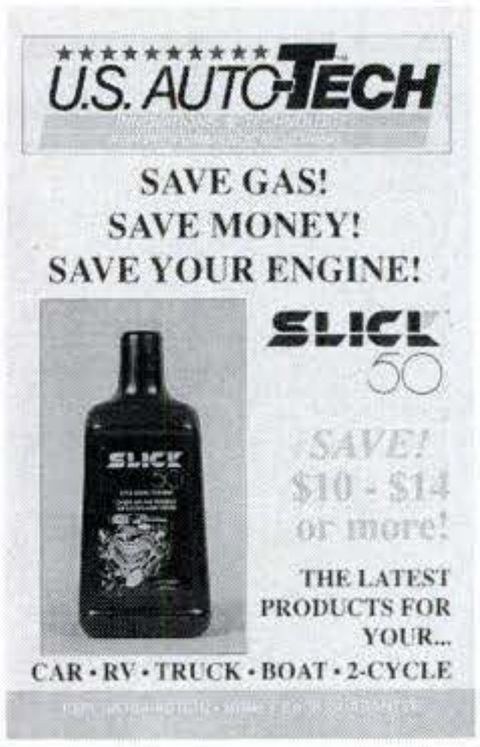

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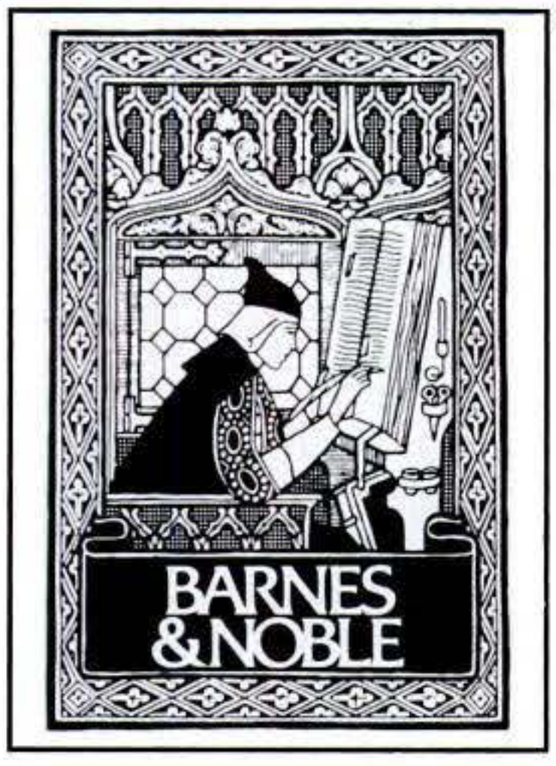

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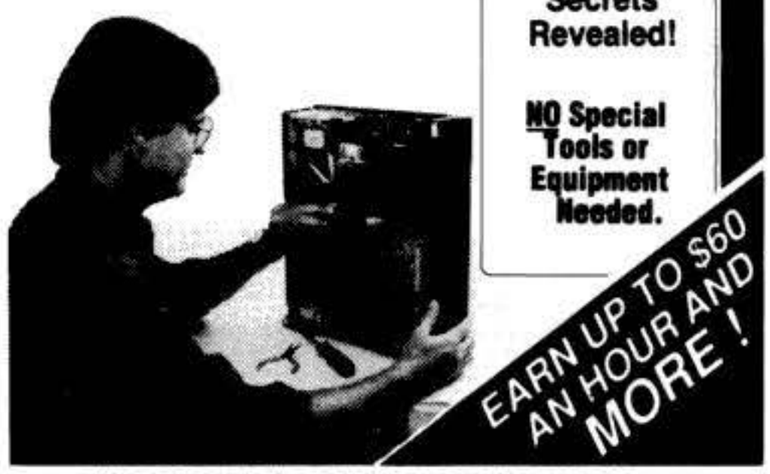

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The trouble with Hubble

[Continued from page 76]

faint-object cameras. These corrective mirrors would be about the size of a nickel.

James H. Trainor, associate director of the Goddard Space Flight Center, says the wide-field camera would be the first to get this treatment. "It was scheduled to be replaced by a second-generation instrument anyway in 1993." That job is to be performed by a shuttle astronaut during an extra-vehicular activity.

High-risk fixes

Two other scenarios for fixing the focus were briefly considered and quickly discarded. One was to retrieve Hubble, bring it back to Earth, and replace the mirror with a waiting backup, presumably free from flaws. That would have posed enormous mechanical risks and enormous costs. The other was to apply a kind of doughnut to the telescope, just as a camera lens is "stopped down" to improve its sharpness. The gain would have been small, and the risk of contaminating the telescope great.

What is inevitable is that coping with Hubble's problems is going to consume more money than was budgeted—lots of it. One estimate is at least $25 million a year. "There's only one place that can come from," says Trainor, and that's the funding for AXAF, the Advanced X-Ray Astrophysics Facility, and SIRTF, the Space Infrared Telescope Facility. Both belong to the series NASA calls Great Observatories. AXAF was scheduled for launch in 1996 and SIRTF by 2000, but Trainor fears they, and maybe other NASA projects, will be delayed by the ripple effect of Hubble troubles. Grandiose schemes like the space station and the Moon-Mars missions are especially vulnerable.

Edwin Hubble died in 1953, after a life devoted to the pursuit of the unknown through astronomy. What might his reaction have been to the troubles of the great telescope bearing his name? To use his own words:

"The search will continue. The urge is older than history. It is not satisfied, and it will not be suppressed."

On Aug. 9, NASA announced that the flaw in Hubble's primary mirror was apparently caused by a spacing error of one millimeter in part of the complex optical system used to gauge precisely the curvature of the mirror during its final grinding and polishing. The guilty part is called a null corrector; a focusing lens is a millimeter too far from one of the corrector's mirrors. NASA stated that "a discrepancy of this magnitude" could account for Hubble's fuzzy focus. PS

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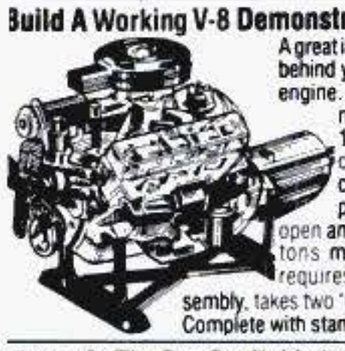

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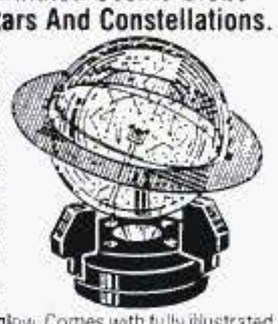
Astropilot Acrylic Illuminated Cosmo Globe Locates Position Of Stars And Constellations.



Our Astropilot Cosmos model is a clear acrylic 5 inch diameter globe depicting 868 stars and all the major constellations of the universe. A horizon ring rests on the globe to determine the visible sky from your location. The globe rests on an attractive black base which contains the illuminator (powered by 4" AA batteries, not included). In the dark, the stars, all 868 of them, will glow. Comes with fully illustrated easy-to-use guide book. **PJ38,909 $34.95**

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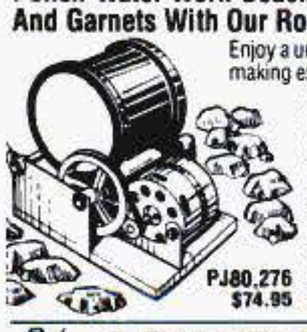

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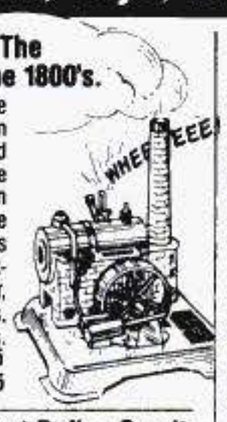

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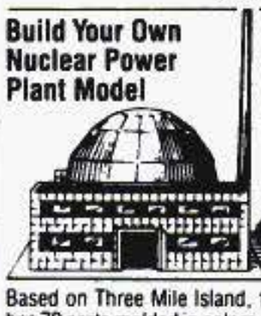

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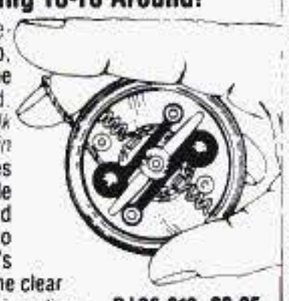

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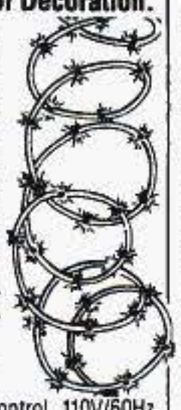

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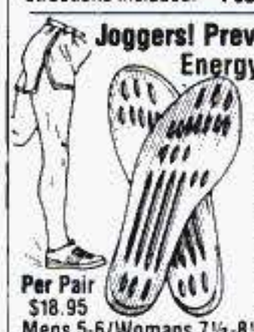

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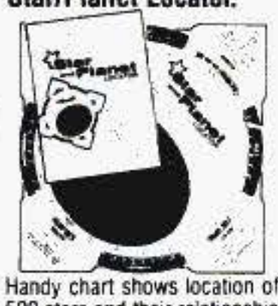

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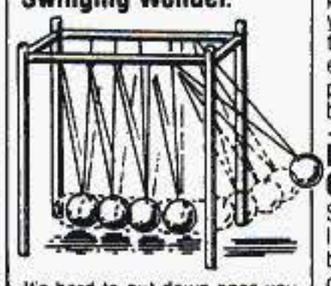

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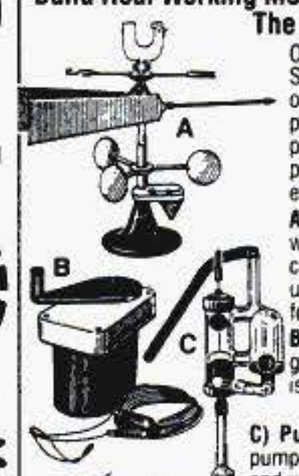

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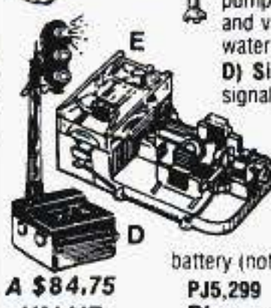

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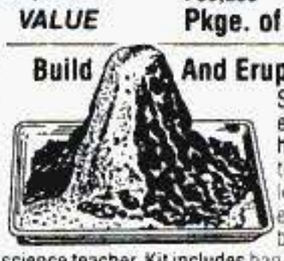

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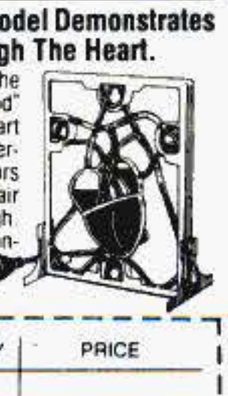

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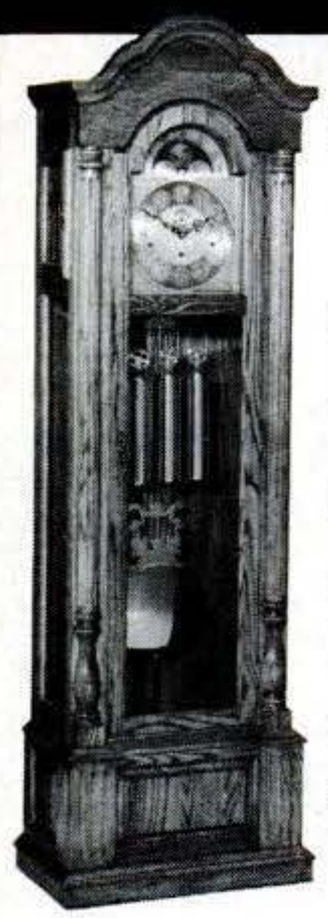

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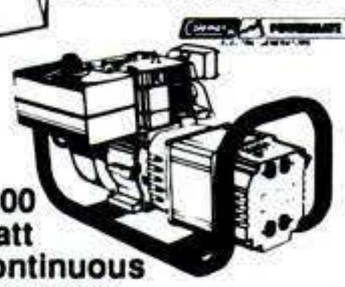

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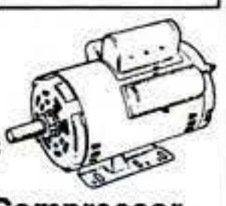

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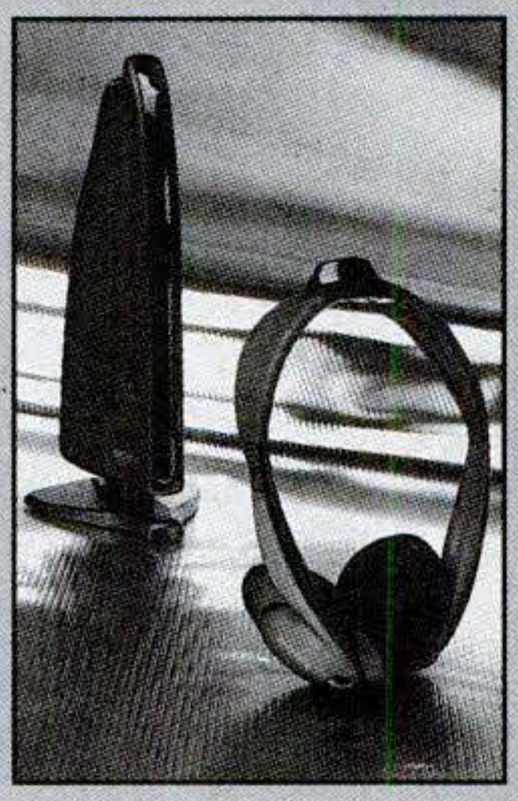

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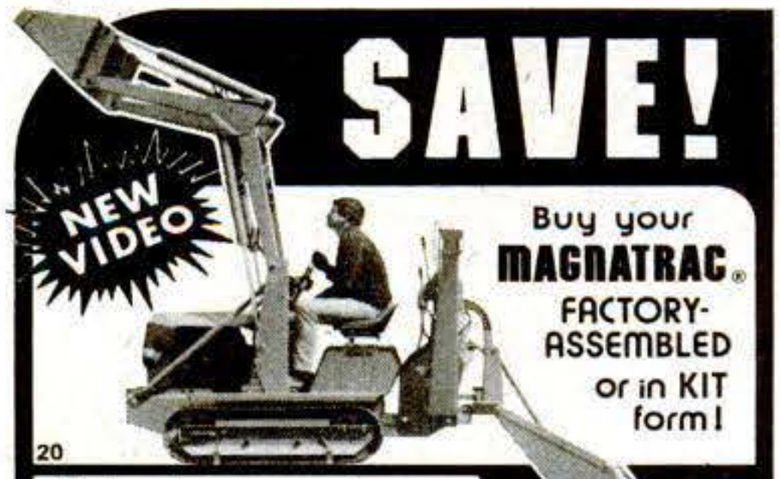

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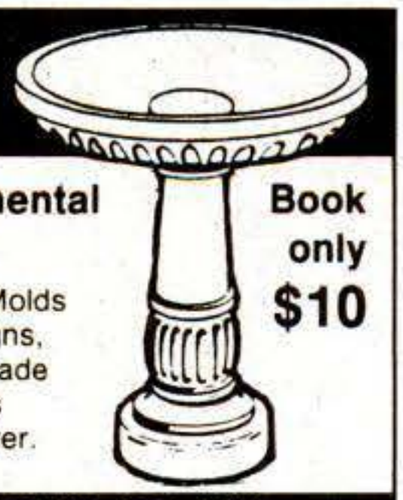

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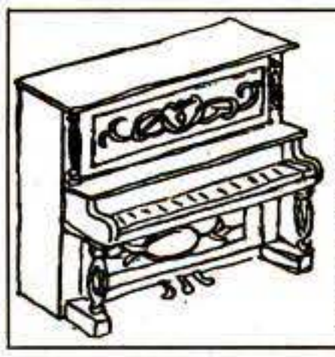

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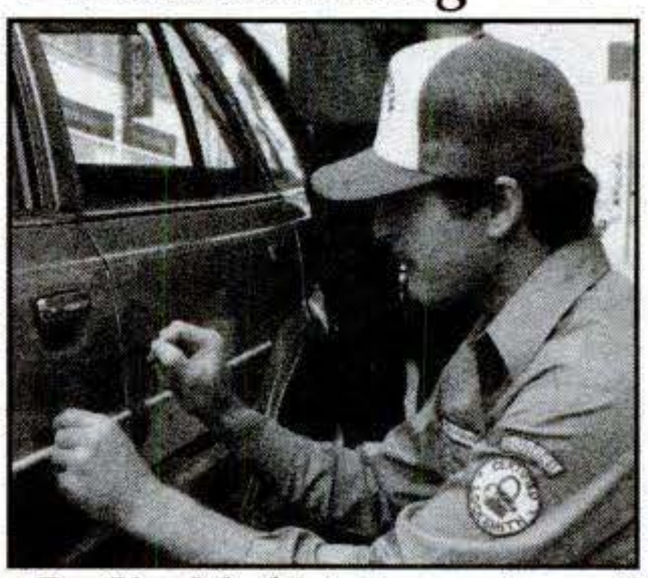

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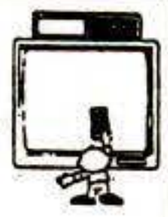

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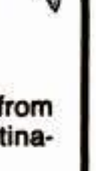

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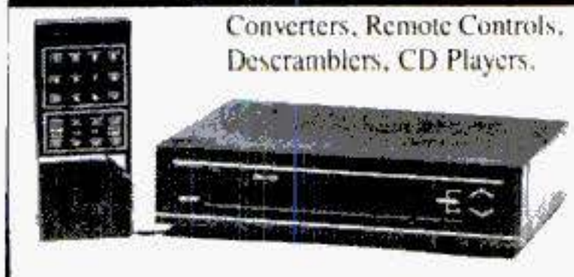

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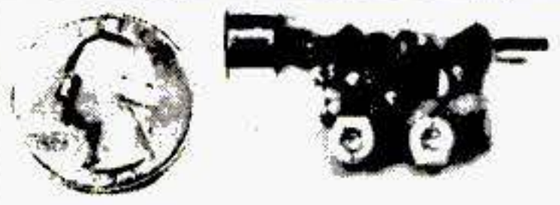

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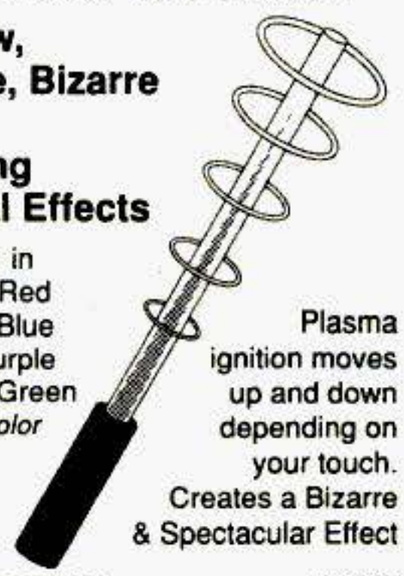

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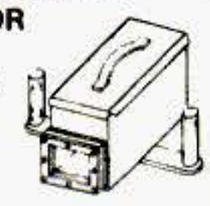

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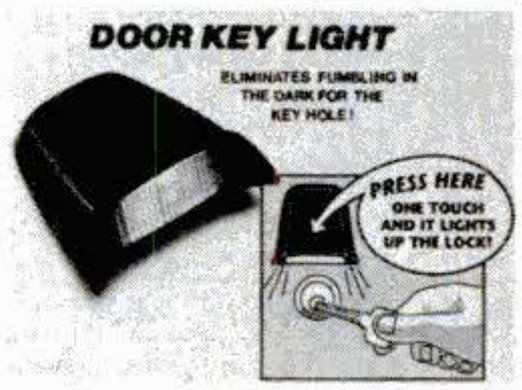

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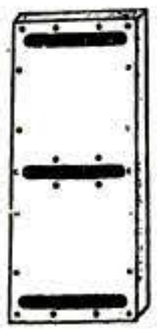

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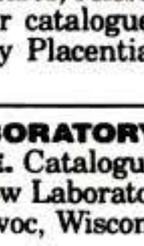

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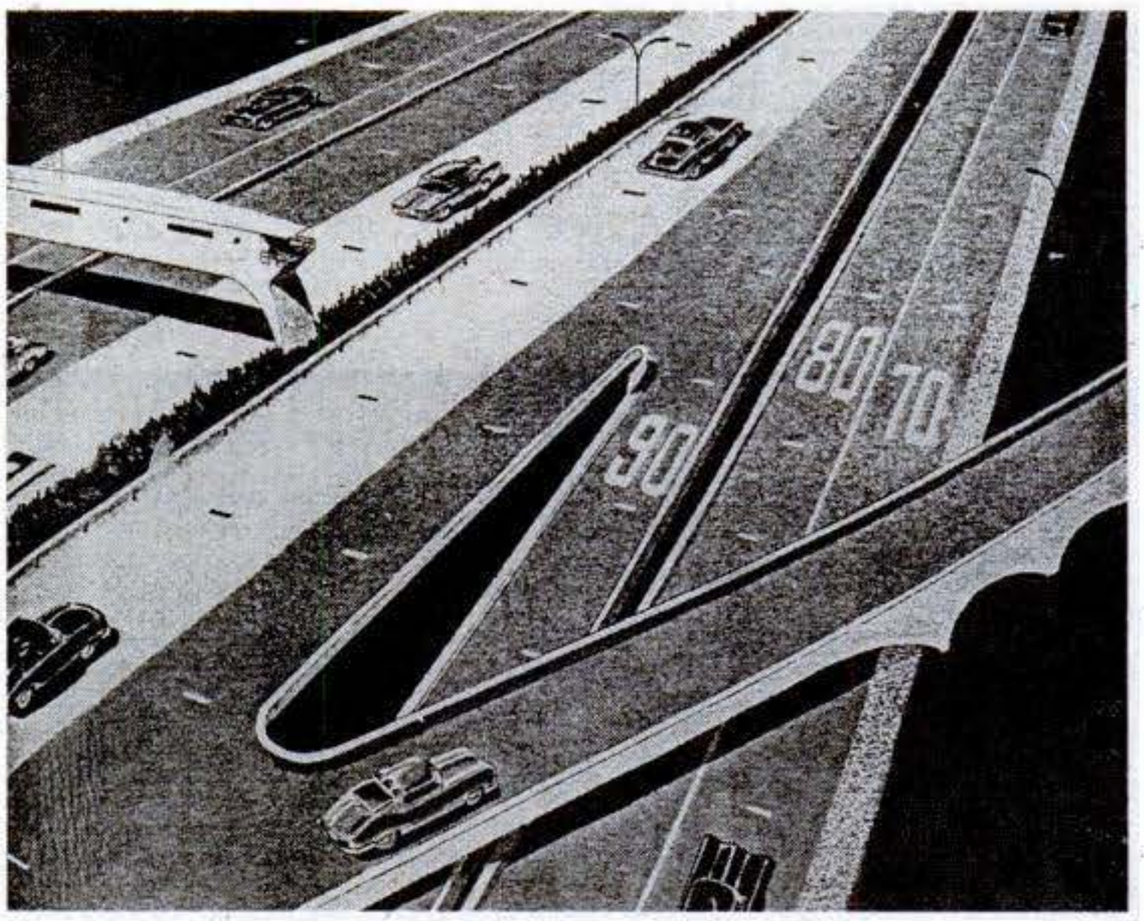
"The wind whistle increases. Your speedometer goes right up past 80 and keeps going: 90, 95, 99.... The other cars fade far behind. A voice override breaks into your radio program: 'Welcome to the Century Expressway.' A 500-mile stretch of wide, clean 'runway' opens ahead of you. You're driving America's first 'speed road'—built for travel at up to 150 mph.

"No dream, the first Century may well be ready for your car within a dozen years. It is not to be an automated highway of the far-out type. It's basically for today's cars and for today's drivers. The engineers who proposed it have bypassed automation; you will be in constant radio contact (like a plane) with passing control towers. And you may also, like a plane, be in radio touch with nearby cars."

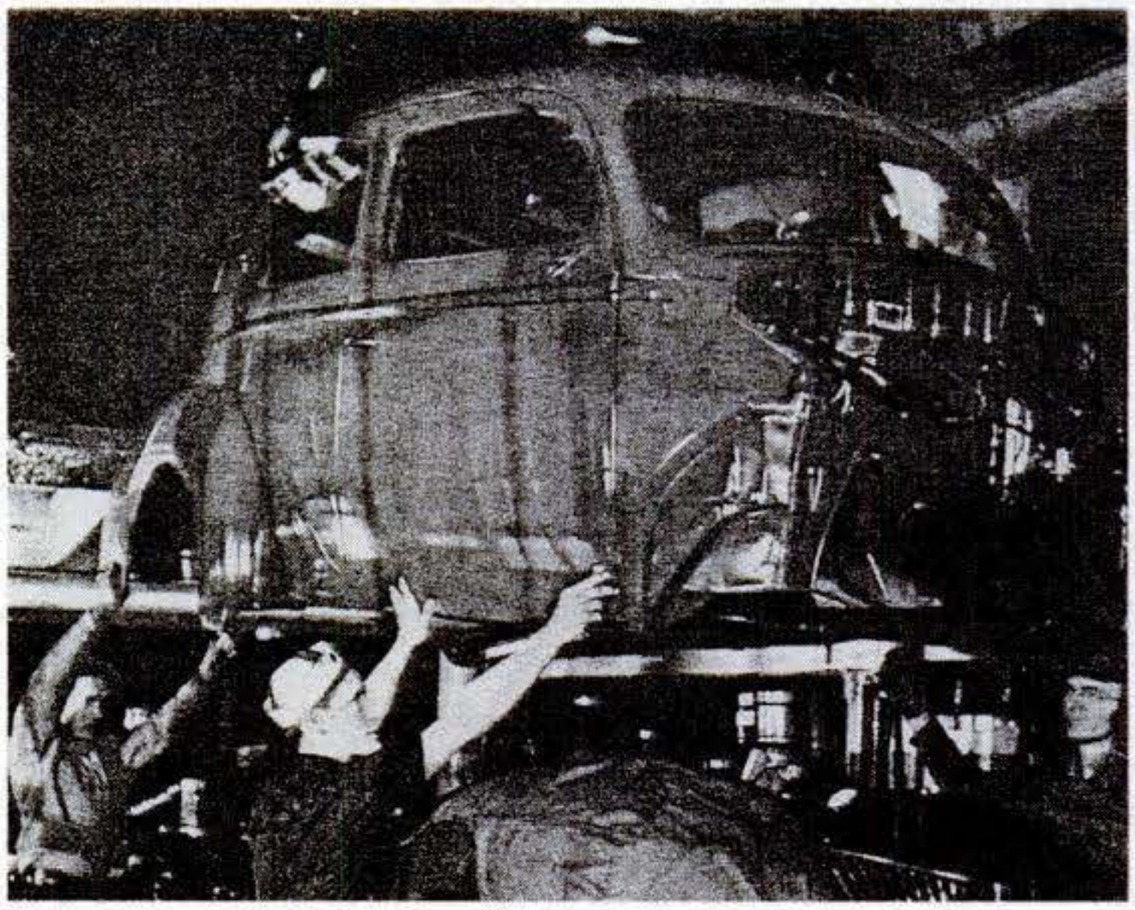


The Century Expressway: a road designed for speeds up to 150 mph.

50 YEARS AGO — OCTOBER 1940

"Five miles west of the heart of Detroit, Mich., on the banks of the River Rouge, is the single largest manufacturing plant in the world. Sprawled over land that could accommodate more than 1,000 football gridirons, this gargantuan factory employs 80,000 men and can turn out 6,000 automobiles in a single two-shift 16-hour day. That's better than one complete, ready-to-run car every 10 seconds.

"A bird's-eye view of the maze of blast furnaces, rolling mills, tool and dye shops, powerhouses, railroads, laboratories, and offices in this giant Ford Motor Co. plant presents the first impression of one vast chaotic tangle. Yet, by a miracle of science and industrial organization, the sprawling parts are blended into a clockwork unit that at one end sucks in raw materials, and at the other blows out a steady stream of gleaming motor cars. To get any idea of the tremendous size of this manufacturing monster, you have to understand that the Rouge plant taps its raw material sources from all around the world."



In the River Rouge plant, the body of a Ford is lowered onto the chassis.

100 YEARS AGO — OCTOBER 1890

"From Cape Cod to Florida our coast is fringed with barrier beaches—reefs of sand that protect the mainland shore from the storm waves of the ocean. Railroad and turnpike bridges have been built, connecting many of them with the shore. Hotels and cottages, clubhouses and bathing-houses, in short, buildings that contribute to our pleasure and comfort have sprung up all over the Atlantic coast.

"Such is the beach of Sandy Hook, which forms the northern extremity of the New Jersey seacoast. Previous to 1778 Sandy Hook was connected with the base of the Navesink Highlands by an isthmus. However, in about 1778 a channel was opened across the isthmus, and a new passage was created due to the tidal currents of the Shrewsbury Inlet, which formed the common mouth of the Navesink and Shrewsbury rivers. This passage gradually closed and in 1810 became impassable.

"It seems the only means of protection is the construction of jetties extending far enough from the shore to intercept the currents, which carry away loose sand. Such jetties have protected the shore at Cape May and added territory to Atlantic City.

"These developments along the Jersey coast show that the ocean front is not fit for building purposes, for it is impossible to protect a house near the water's edge from ruin in the heaviest of storms. Many cottages are now much nearer to the water's edge than they were a few years ago because of the wear of the shore by currents."

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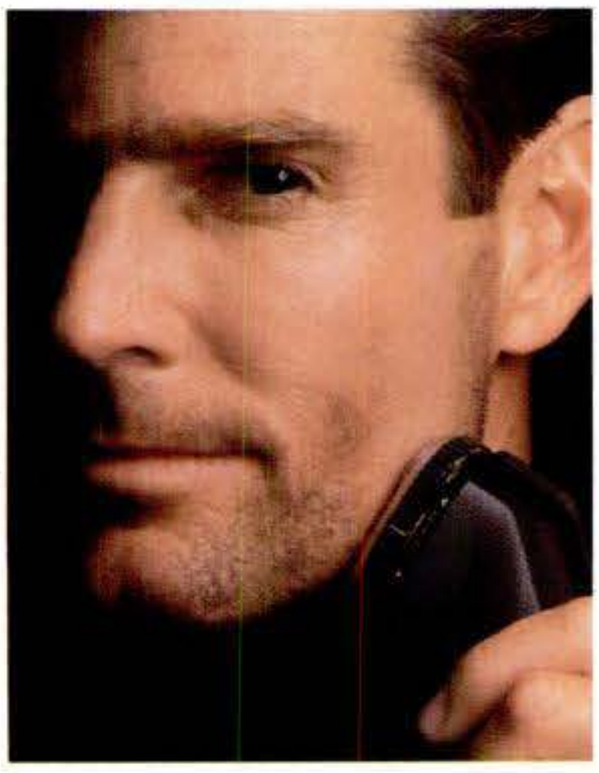

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